**THE EFFECT OF VALUES
ON
SYSTEM DEVELOPMENT PROJECT OUTCOMES**

THESIS

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AFIT/GSE/ENV/09-M08

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Abstract

In order to understand why organizations make certain decisions and target certain outcomes, it is useful to understand their priorities and preferences, commonly referred to as "values." This research explores the relationship between the technical values held by system development teams and the operational effectiveness of the systems those teams produce. Specifically, it examines the impact of a value set called FIST (Fast, Inexpensive, Simple, Tiny) on DoD and NASA system development projects, and investigates the correlation between the FIST values and operational outcomes.

The findings show that the FIST value set enhances project stability, increases the project leader's control and accountability, optimizes failure, fosters "luck," and facilitates learning. These benefits of the FIST approach all support the goal of ensuring the organization delivers systems which are "available when needed and effective when used." FIST is therefore recommended as an effective approach to system development, and several heuristics are provided to facilitate understanding and application of these values.

This project is dedicated to all the military acquisition reformers and researchers who went before me and upon whose broad shoulders I stand. Men like Col John Boyd (USAF, ret), Col Chet Richards (USAF, ret), Col James Burton (USAF, ret), Chuck Spinney, Pierre Sprey, Winslow Wheeler, and Maj Frederick Stark, gave me much inspiration and set an example I have tried to follow.

It is also dedicated to all who will serve in the years to come and who will strive to provide our armed forces with effective and robust weapon systems.

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THE EFFECT OF VALUES

ON TECHNOLOGY DEVEOPMENT PROJECT OUTCOMES

Every gun that is made, every warship launched, every rocket fired signifies, in the final sense, a theft from those who hunger and are not fed, those who are cold and not clothed. We pay for a single fighter plane with a half-million bushels of wheat. We pay for a single destroyer with new homes that could have housed more than 8,000 people.

                                                    - President Dwight D. Eisenhower, April 19, 1953

I.   Introduction

This research project explores the relationship between the organizational values held by system development teams and the operational outcomes of the systems those teams and organizations produce. Specifically, it examines the impact of a set of values called FIST, which stands for Fast, Inexpensive, Simple and Tiny, asking to what extent (and under what conditions) the FIST values contribute to the development and delivery of effective, reliable systems. It then offers some suggestions on ways to implement this value set, in order to improve the operational performance of military development projects.

FIST Origins

In 2002, when I was a junior Captain assigned to the National Imagery and Mapping Agency (now called the National Geospatial-Intelligence Agency), I began an informal, independent investigation into high-performance military technology development programs. Intrigued by organizational behavior research and the work of management gurus like Peter Drucker and Tom Peters, I examined the groups and

organizations responsible for developing successful technologies and weapons. I also investigated the factors leading to failed projects.

The early research was informal but rigorous. It focused on analyzing spectacular failures like the Navy's A-12 Avenger and prominent successes like the Air Force's F-16 Falcon. The cases I selected turned out to be what Flyvbjerg refers to as *critical cases, extreme cases* and *paradigmatic cases* (Flyvbjerg, 2006:230), although I would not encounter those terms until some years later. Flyvbjerg argues for the importance of using atypical cases in building and testing theories, explaining "Atypical or extreme cases often reveal more information because they activate more actors and more basic mechanisms in the situation studied." (Flyvbjerg, 2006:229)

As the research progressed, I quickly discovered that many researchers and writers had explored various pieces of the defense acquisition puzzle and produced a bewilderingly large set of recommended solutions which were often overlapping, mutually exclusive and/or internally contradictory. Further, many of the reform efforts seemed to focus solely on improving programmatic outcomes (cost and schedule performance) rather than operational effectiveness. I was not satisfied that anyone had provided a comprehensive-but-feasible prescription for actually improving the *operational* effectiveness of defense acquisition projects. I also did not find much evidence that the recommendations led to the desired results, either programmatically or operationally.

Some sources, such as the 1986 Packard Commission or Ross McNutt's 1989 PhD thesis at MIT, focused on excessive timelines as the central problem in military technology development efforts. A few (Fitzsimonds and van Tol, 1994) explored the

relationship between budget size and operational innovation, concluding that "innovation is not necessarily or even primarily a function of budget. Many… innovations came at a time of low budgets…" (Fitzsimonds and van tol, 1994:29). Others discussed the role of complexity, both organizational and technological. Over a period of several years, the work of these and other researchers, along with my own independent observations, began to coalesce into something resembling a unified theory of effective military system development, which focused on developing systems that would be *available when needed and effective when used*.

In a series of articles published by Defense Acquisition University, my colleague Maj. Chris Quaid and I outlined the four elements of what has become the FIST model for system development. The series culminated in a capstone article titled *FIST, Part 5*, which was published in *Defense AT&L's* May/June 2006 issue. This article summarized and synthesized our previous research findings, and offered the FIST value set as an effective way to deliver innovative, reliable technology systems to military customers, with a firm focus on operational effectiveness as the primary measure of merit.

Much of our original FIST research up to that point was based on personal experience and observation, and was admittedly anecdotal. However, the FIST model was also built upon rigorous, academically-validated research performed and published by others, including several of the previously mentioned sources, along with reports by the Government Accountability Office, other researchers across the services and academia, and several congressional blue ribbon panels.

Upon hearing of our approach, Dr. Alexander Laufer of Israel's Technion University (and the former Editor-in-Chief of NASA's program management journal

ASK) described Maj Quaid and I as "reflective practitioners," a label we immediately embraced.

The term reflective practitioner comes from Donald Schön's book *The Reflective Practitioner*, published in 1984. Reflective practice generally refers to a research methodology involving the deliberate examination of one's experiences combined with formal academic knowledge in order to establish deeper understanding of the practice in question. Today, this methodology is most often used in the fields of medicine and education, but Schön's book explicitly applies it to practitioners from a wide range of fields, including architecture, engineering and management. In this thesis paper, the practitioners of interest are referred to as "project leaders," a general term that includes program managers, systems engineers, system architects, system operators, commanders and other people responsible for leading the development of a technology system.

Schön argues that "competent practitioners usually know more than they can say. They exhibit a kind of knowing-in-practice, most of which is tacit." (Schön, 1984:viii). This is counter to the prevailing Positivist academic worldview, which tends to operate under "the conviction that empirical science was not just a form of knowledge, but the only source of positive knowledge in the world." (Schön, 1984:32). The initial FIST research clearly belongs in the realm of reflective practice, since its foundation largely rests on "knowing-in-practice," and was bolstered by, rather than established on, academically oriented studies.

Schön goes on to show that practitioners often have "a capacity for reflection on their intuitive knowing in the midst of action… [which is] susceptible to a kind of rigor that is both like and unlike the rigor of scholarly research." (Schön, 1984:ix) This

intellectual rigor, which is "both like and unlike" academic rigor, is precisely what we aimed to achieve in our initial research. Our experience resonates strongly with Schön's description that "our knowledge is *in* our action." (Schön, 1984:49, emphasis in original).

Thus, the FIST model has its roots in years of reflective practice, although the formal term, like Flyvberg's case categories, was something we encountered only after several years of actually doing it. This thesis is therefore the continuation of a multi-year research project that began as the result of reflective practice. It aims to produce an original academic assessment of the FIST model's applicability and limitations, and to inject a more formal type of academic rigor into our previous reflective analyses.

What are Values?

Values are statements of priorities and preferences. An organization's values typically answer the questions "What is important?" or "What is good?" The answers to these questions shape the measures of merit project leaders use to assess and shape a system development project. When an organization expresses the FIST values, they are stating "It is good and important to be fast, inexpensive, simple and tiny." The technical measures of merit driven by the FIST values, therefore, are oriented around low-cost, short schedules, simplicity and smallness.

Values are primarily cultural artifacts, and their existence within an organization is determined by the presence of *value clues*. Value clues may be measurable, taking the form of physical, procedural, formal or otherwise visible features, but are also often intangible, taking the form of an unmeasurable "sense" that the particular value is important and good.

Thus, values can be either explicit or implicit. Just as there is a difference between an organization's intended strategy and the realized strategy, there is also often a difference between *stated* values (which are often idealized) and the actual values which are put into practice by the organization's members.

Organizational behaviorists point out that an organization's *realized* strategy is a combination of stated and emergent strategies. Similarly, the *realized* values are a combination of intended values (which the organization aims to adopt) and emergent values (which the organization actually demonstrates by its actions and behavior). This is important because while an individual within an organization may make statements supporting a particular value, these statements will need to be measured against actual behavior and decisions. That is, the value clues hidden in the project leader's actions need to be considered when assessing an organization's values, alongside whatever explicit value statements the individual or other organizational leaders might make. Implicit or unconscious values may have a significant effect on the organization's decision-making process and on the project's eventual performance.

Why Look at Values?

Values guide and shape organizational behavior across the entire spectrum of decision making, from requirements definition and system design to organizational structure and process establishment. In fact, "Values are often considered the bedrock of corporate culture. Many corporate leaders have validated these observations about the central importance of organizational values." (Posner, Kouzes, Schmidt, 1985: 293). So, if we want to understand why an organization makes certain decisions (which lead to particular outcomes), it is important to understand the organization's values.

A paper titled *Strategic Planning 101* points out "… values underlie the decision-making process. Ignoring the values of an organization is disastrous for a strategic plan because regardless of the plan, major and minor decisions will align with the culture but not necessarily with the mission." (Workstar, 2008).

According to Seevers, "Values are enduring because they are neither completely stable or unstable, but rather change in accordance to the changing physical, social, and spiritual environments of the individuals and groups that embrace them." (Seevers, 2000:71). This blending of stability and openness to change gives values a dynamic, powerful ability to resist irrelevance or obsolescence, making them an important framework for understanding an organization's behavior.

Values have an enormous impact on system design, from requirements definition to the final operational testing, and weapon system design is no exception. As Tobias et al point out, "Weapons, too, reflect the societies that produce them." (Tobias et al, 1982:382). The authors briefly compare Russian and German tanks from World War II:

> One of the best German tanks of World War II was the Panzer IV. It represented not only the high state of German technology, engineering skill, and precision workmanship, but the *Blitzkrieg* style of war as well. The best Russian tank of the period, the T-34, was equally typical of Soviet values. The T-34 was simply designed and easily manufactured, but eminently reliable (particularly well-adapted to the Russian winter) and cheap. Moreover, being easy to operate and maintain, it could be manned by technically unsophisticated crews… Despite their simplicity, the T-34's generally prevailed over the Panzers." (Tobias et al, 1982:382).

Thus, we see that a country's values tend to influence both its style of warfighting and the shape of its weaponry. American values are examined in the Discussion section of this paper.

The FIST Value Set

The FIST value set was summarized in a capstone article by Quaid and Ward titled *FIST: Part 5* (Quaid & Ward, 2006a). They explain:

> The components of FIST are, first and foremost, statements of professional values. They are characteristics, attributes, or entities that are judged to be of greater worth than the alternatives. They describe principles, standards, and qualities that are deemed worthwhile and desirable… Like any set of values, FIST can be understood as a collection of philosophical assertions, designed to drive actions and inform decision making. (Quaid & Ward, 2006a:30-31).

Although the FIST value set has four parts, it is properly understood as a single idea. An attempt to remove some portion of this value set is likely to impact the program manager's ability to implement any of it at all. This attribute of singularity is similar to Laufer's explanation of a set of principles in his book *Breaking The Code of Program Management* (Laufer, 2009). Laufer writes:

> The implementation of any one principle and its impact on project success depends on the implementation of all the others. In order to compensate for the inability to fully adhere to a principle, be prepared to modify the implementation of the others as well as to adjust project expectations. (Laufer 2009:183).

Accordingly, this research treats the FIST value set as a single entity, in which the neglect of any one component will impede an organization's ability to implement the remaining components. For example, decreasing a program's budget while simultaneously increasing the schedule is inherently untenable, because it takes time to spend money and it takes money to spend time. Similarly, emphasizing speed while increasing the system's complexity leads to contradiction and reduces the ability of the team to fully express either value.

Properly understood, the FIST values are mutually reinforcing, not mutually exclusive. Organizations which attempt to express the FIST values often discover that

implementing one of the values tends to *improve* the organization's ability to implement the other values. As Spinney explains, "Operating costs are strongly related to the size, technical complexity and operating tempo of the military forces. Increasing the complexity of weapons increases the size and complexity of the support tail, and operating costs go up…" (Spinney, 1985:185). The inverse of Spinney's observation is also true – reductions in a system's complexity tends to decrease the size and complexity of the support tail, so operating costs go down, and time to delivery is decreased.

The programs evaluated in this research are given a score in each of the four categories, an F-score, I-score, S-score and a T-score. The four scores are compiled into an overall FIST score, which is then compared with the system's operational outcome. The following section introduces each of the four FIST components.

F: FAST IS GOOD

Since the mid-1980's, speed has become essential to business—to such an extent that many authorities argue that speed is the single most significant basis for competitive advantage in the years ahead. (Laufer 2009:33)

The F in FIST stands for Fast. Organizations often express this value by taking steps to encourage and reward short development timelines. These steps can include strong, explicit, frequent affirmations of the importance of speed from senior leaders, formal contractual commitments to maintaining deadlines and concrete steps taken to actively reduce planned development timelines. In an environment where Fast is valued, participants are rewarded for meeting or beating contract deadlines, milestones and delivery dates. When Fast is not valued, schedules tend to be very long, and requests for schedule slips are viewed as a reasonable approach to correcting difficulties.

This aspect was introduced in an article titled "It's About Time" (Quaid and Ward, 2006b). The article begins with a look at some historical studies and pronouncements, and points out that for over twenty years, there has been a wide agreement that, in the words of the 1986 Packard Commission, "An unreasonably long acquisition cycle … is a central problem from which most other acquisition problems stem." The article provides several other statements in support of the importance of speed:

> **1986**: "Many have come to accept the ten-to-fifteen year acquisition cycle as normal … We believe that it is possible to *cut this cycle time in half*." —Packard Commission Report

> **1986**: "The most important way technology could enhance our military capability would be to *cut the acquisition cycle time in half*." —Chairman of the Joint Chiefs of Staff

> **1994**: "Deliver emerging technology to troops in *50% less time*." —Federal Acquisition Streamlining Act (FASA)

> **2003**: "advanced technology shall be integrated into producible systems and deployed in the shortest time practicable." –May 2003 update to DoDD 5000.1

Dr. Alexander Laufer similarly examined a series of studies on the issue of project timelines, and came to a similar conclusion about the impact of excessive timelines and schedule delays. He writes "while an engineering cost overrun of 50 percent impacts overall profitability by just 4 percent, a time delay of six months in project completion can result in a 32 percent loss in after-tax profit." (Laufer, 2009:33). The data provides clear support for the Fast value, and yet this value is often absent from project teams.

Along with helping to avoid cost impacts, the Fast value proposes that short timelines provide:

- Increased stability in requirements and funding
- Decreased personnel turnover
- Greater accountability

- More accurate user feedback (build the system quickly, field it quickly, gain feedback quickly, repeat…)

- Smaller budgets (because time = money)

- Closer match to the operational environment's needs

- Decreased risk of obsolescence

- More meaningful metrics (less time for collection and analysis of pointless metrics, decreased risk of collecting and analyzing out-of-date metrics)

- Enhanced opportunities for learning from experience

These are some of the more prominent reasons given for identifying speed as "important and good." Program managers who hold to the FIST values therefore explicitly embrace the value of speed, and take concrete steps to demonstrate the belief that being fast matters. Projects where speed is clearly identified as "important and good" have a high F-score.

A question which often comes to mind in discussions about the Fast value revolves around the difficulty of assessing the time duration of a system development project. When should we start and stop the clock? Did the project begin when the Request For Proposals was sent out, when the contract was signed, or at some other, perhaps earlier, point? How far back into the basic research process should one go? And on the other end of the timeline, should we stop the clock when Initial Operational Capability (IOC) is declared, when the system is first used operationally, or is there a better milestone to indicate the end of the development? It turns out, these questions are not important in the context of this research.

When assessing the presence of the Fast value, it is not necessary to have a concrete, specific measurement of the amount of time spent on the project. We must simply investigate whether the development team (government and contractor) *valued*

speed, whether project leaders considered it "important and good" to be fast relative to other efforts of a similar nature. Delivering in three months or three years is not the point. Instead, this research looks for value clues, such as an aggressive schedule, contractual incentives for early delivery, sacrifices of other priorities (performance, capability, etc) to ensure timely delivery, or a willingness to accept higher levels of risk rather than accept a delay. Ultimately, the Fast value means that, *for this type of system development project*, the timeline is aggressive, regardless of the specific amount of time spent.

Thus, the presence of the Fast value is not determined by rigorously documenting the program's start and stop times and comparing it to some standard. There is no absolute amount of time which constitutes a Fast program, although the GAO notes that a development timeline greater than 5 years is probably too slow (Dodaro, 2008:26). A correlation between values and programmatic outcomes should not be assumed, and adherence to the Fast value does not guarantee the project will deliver on time. In fact, even a late delivery might have been driven by the Fast value. The question is whether or not the team thought it was important and good to be fast, regardless of whether they achieved their schedule goal or not.

It must also be noted that time pressure and the Fast value are not the same thing. The Fast value is strategic and (perhaps ironically) long-term, aimed at delivering a functional, sustainable technology solution as quickly as possible. Mere time pressure, in contrast, is often tactical and short-term, potentially introducing extensive delays down the road, in effect sacrificing tomorrow to achieve the *appearance* of fast results today. This is reflected in the saying "take the time to do it right the first time, so you don't have to do it over."

The Fast value does encourage short, "insufficient" timelines, but simply being hasty is not the same thing as being Fast. For example, bluntly accelerating an existing schedule and cutting corners on essential tasks is not consistent with the Fast value. This kind of brute-force approach often leads to unintended delays over the long run, as project members have to go back and do (or re-do) work that could have been accomplished sooner if it had been executed correctly in the earlier attempt.

An article in *Harvard Business Review* illustrates this difference between Fast and hasty, using a parable of a man pushing an apple cart to a distant marketplace. When the man asked a bypasser how long it would take to get to the market, he was told "If you take your time, it'll take about an hour. If you go fast, it'll take all day." (Perlow and Williams, May 2003). This counterintuitive advice makes sense because the man's applecart was full and the road was bumpy. If he rushed, he would spend all day stopping to pick up the apples that bounced out of his cart. Like the story of the tortoise and the hare, the fastest way for the man to get to the market actually required him to walk slowly (and not stop).

Giving in to short-term, tactical time pressure and clumsily "speeding" tends to result in taking *more* time, not less, and ultimately results in a slower delivery. Being hasty—i.e. speeding—is therefore not consistent with the assertion that "it is important and good to be fast," because hastiness delays the ultimate delivery of the system. The Fast value, in contrast, takes a strategic point of view, and is not satisfied with the shallow appearance of speed.

As with many types of measurement and assessment, distinguishing between being Fast and being hasty can be difficult to do *in situ*, but is is possible, particularly for

project leaders who are reflective practitioners. If too many apples are falling out of the cart, the program is probably being hasty. That is, if the time allotted is physically insufficient to accomplish the activities which are truly essential, the program is speeding and not expressing the Fast value. However, determining what is "essential" and figuring out how many apples we can afford to lose along the way is often a difficult question, and is a matter for professional judgment and experience.

The Fast value leads program managers to trim unnecessary activities. It also tempts them to cut essentials, which can cause significant problems and even cause the program to fail. The question on the table is whether the tool can be used effectively, without injecting undue risk to the overall outcome. The best approach appears to involve relying on experienced, talented program managers who are wise enough to distinguish between necessary and unnecessary activities when making decisions related to speed.

Some leaders consider the risk of speed to be acceptable. Hector Ruiz, CEO of AMD, tells his employees "Please, go get speeding tickets. I don't want you to get parking tickets." (Kirkpatrick, 2006:118). This willingness to metaphorically lose some apples along the way, when done deliberately and with a positive view of failure as a learning experience, is entirely consistent with the Fast value.

I: INEXPENSIVE IS GOOD
The I in FIST stands for Inexpensive. Organizations often express this value by deliberately pursuing low-cost solutions and establishing contractual incentives to reward cost under runs. They often make formal commitments to maintain their budget and are willing to sacrifice other attributes, including performance or redundancy, to ensure the program cost stays low. When being Inexpensive is not valued, project leaders seek to

increase their budget as a means of solving problems, and work hard to ensure that next year's budget is not decreased.

This piece of the FIST value set was first introduced in an article titled "Doing Less With More," (Ward, 2004). The article begins with the assertion that being overfunded limits the organization's ability to be innovative, and argues that having a small, "insufficient" budget actually leads to better technology solutions and superior operational outcomes.

The Inexpensive concept is based largely on research by Pierre Sprey (Clark, 1984) and Fitzsimonds & van Tol (Fitzsimonds & van Tol, 1994). In a widely cited research project, Sprey argued for the superiority of "cheap winners" over "expensive losers." Similarly, Fitzsimonds and van Tol's research indicated that "militaries are driven to innovate… by the need to make more efficient use of shrinking resources…" They conclude "Innovation is not necessarily or even primarily a function of budget." (Fitzsimonds & van Tol, 1994:26, 29).

Spinney also demonstrated an inverse relationship between cost and effectiveness. In an analysis of missile development efforts, he writes:

> … as cost and complexity increase, fewer missiles are projected to be fired. This implies that cost is a major factor in shaping this program. Although the increased costs are justified in the attrition view by promised increases in lethality, the increased costs lead to *less* confidence in predicted lethality… As weapons get more expensive, they are fired less frequently—and less realistically—in training and testing. (Spinney, 1985:91).

This inverse relationship between cost and effectiveness is one of the reasons often given for holding to the Inexpensive value. The components of the FIST value set are closely interrelated and mutually reinforcing. The behaviors that emerge from one

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value often overlap with the behaviors driven by the other three values. Thus, the Inexpensive value is closely related with both Fast and Simple, as speed and simplicity are often pursued for the sake of keeping the overall costs down.

When a program manager determines it is important and good to have a small budget, the schedule and degree of complexity both naturally tend to shrink, as does the size of the project team. Inexpensive solutions tend to leverage existing, mature technology, rather than pursuing the more expensive path of new development, which is a sign of simplicity. Thus, the use of mature technology is a value clue that can increase the system's I-score and S-score.

Further, lower costs tend to require shorter schedules and reductions in complexity (both organizationally and technologically). So, any particular value clue statement might be an expression of more than one component of FIST, further supporting the assertion that FIST is one idea, not four.

S: SIMPLE IS GOOD
The S in FIST stands for Simple. Organizations often express this value by reducing complexity in their organization and procedures as well as in the technology systems they develop. Program managers who value simplicity tend to focus their projects on a narrow, stable set of modest operational requirements and aim for "the shrewd application of available technology," (AF Studies Board, 2008:32), rather than a frequently changing and wide-ranging collection of unproven, high-tech, beyond-the-state-of-the-art objectives. When Simple is not valued, project leaders tend to view complexity as a sign of sophistication and pursue complex, high-technology solutions for their own sake, rather than because they meet the actual operational needs.

This piece of the FIST value set was first introduced in an article titled "The Simplicity Cycle," (Ward 2005b), and was further refined in a book of the same name (Ward, 2005c). Just as the Fast value distinguishes between being Fast and being hasty, the Simplicity Cycle draws strong distinctions between simplisticness and simplicity, as well as between complexity and complicatedness.

The fundamental idea behind the Simplicity Cycle diagram is that system development activities move through a cycle, beginning with a simplistic concept which becomes more complex as it improves and new capabilities are added. Once a certain critical mass of complexity has been achieved, optimized solutions are the result of a *simplification* effort, resulting in a simple (not simplistic) solution. Any further increases in complexity beyond that critical mass point actually *reduce* the system's value (performance, reliability, etc). Figure 1 shows the Simplicity Cycle diagram.
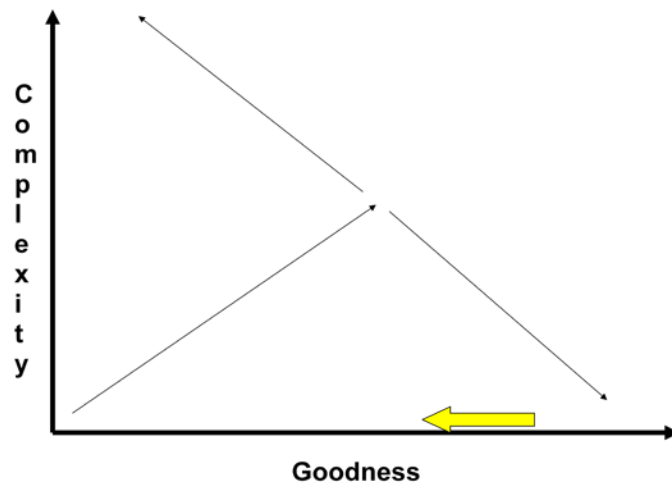
Figure 1: The Simplicity Cycle

This diagram illustrates the idea that optimized simplicity is necessarily built on a foundation of experience and complexity. Using mature, proven technologies is an example of genuine simplicity, building as it does on previous experience. The converse

is also true—relying on new developments and unproven solutions leads to simplistic or complicated solutions, which get a lower S-score. Please note: simplistic approaches receive a low S-score, despite having a minimal level of complexity, because *simplisticness* is inferior to *simplicity*, and simplistic approaches do not indicate the presence of the Simple value.

Organizationally, simplicity means relying on people's talents and experience to achieve objectives, instead of using elaborate, formal (i.e. complex) procedures. A simplified organization relies on trust and talent rather than erecting intricate mechanisms to audit, monitor, control and dictate behavior. Simply stated, Theory Y management is simpler than Theory X.

The Simplicity Cycle defines complexity as "consisting of interconnected parts," (Ward, 2007), so a system can have either a high or low degree of complexity. Simplicity, therefore, requires minimizing the number of components and interfaces used, whether those components be parts of a system or people on a project team.

A large number of components means a low T-score, naturally (for a description of the Tiny value, see the following section). But a large number of components also increases the system's complexity, and therefore reduces the project's S-score. For example, three components have three interfaces and three possible communication paths. But doubling the number of components to six increases the number of possible communication paths to 15, a factor of 5 increase, as shown in Figure 2. Thus, in some situations, size has a more significant impact on a system's S-score than its T-score.
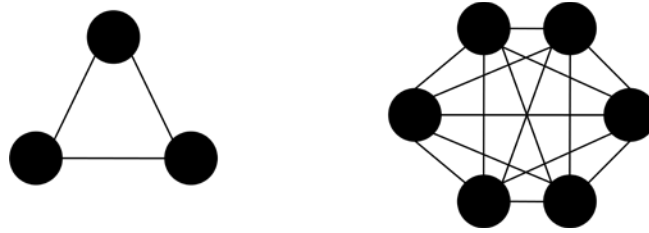
Figure 2: Communication Paths

As Figure 2 shows, complex entities—be they systems or organizations—have a greater number of interactions to manage. This management has a cost, naturally, so complex systems tend to require more money than simple ones do. McCurdy points out that "the ability of a team to solve problems informally is limited by the potential number of communication channels within the team." (McCurdy, 2001:153). As potential communication channels increase, so does the complexity, while the ability to solve problems is diminished.

McCurdy identifies simplicity as a critical element in NASA's Faster, Better, Cheaper initiative. He writes:

> Low-cost missions of the lowest complexity… did very well. As projects moved up the cost/complexity curve, failures occurred. It did not matter whether the more complex "faster, better, cheaper" projects sat above or below the adequate—spending line. All of the more complex projects failed or were impaired, regardless of whether their managers spent too little or too much. (McCurdy, 2001:27)

McCurdy goes on to point out that the "primary route to simplicity runs through size reduction," (McCurdy, 2001:21), once again highlighting the interrelated nature of the FIST values. Small is simple and simple is small.

Tobias et al also point out that simplicity also tends to enhance availability, while complexity degrades it. They write "complex planes have more things that can go wrong,

so they spend more time in the shop. As a result, we not only can buy fewer, but those we have are down for maintenance more often." (Tobias et al, 1982:368). Quoting an unnamed naval officer, they further support the link between complexity, increased cost and diminished availability:

> Expensive airplanes are complex airplanes, and complex airplanes, over the past ten to fifteen years, have been the bane of our existence. The costs of keeping a stable of these complex machines in fighting trim is astronomical. (Tobias et al, 1982:369)

Tobias et al summarize this into a simple rule: "as weapons increase in complexity, their reliability declines." (Tobias et al, 1982:369) This degradation of reliability, combined with increases in cost, is further complicated by a vicious circle, which Tobias et al describe this way:

> Complexity pushes up costs; since expenses go up faster than available funds, production runs decline, which pushes up unit costs further still, leaving the Pentagon with even fewer weapons. Yet, at the same time, these weapons are less reliable because of their complexity, which results in still fewer being available for service, and those that are have higher maintenance costs." (Tobias et al, 1982:370)

Because integration is such an important capability for virtually every DoD system, a project leader's appreciation for the systems engineering concept of high cohesion / low coupling can have a major impact on a system's S-score. High cohesion and low coupling can greatly simplify a system's development, testing, operations and maintenance efforts, so project leaders who value high cohesion / low coupling tend to get a higher S-score.

Along with the principle of high cohesion / low coupling, simplicity includes the concept of specialization and generalization. That is, specialization tends to involve

simplification, as each component in the system is focused on accomplishing a particular, narrowly-defined function. Generalized, multi-mission systems require many more components and interactions in order to accomplish a wider range of functions, which increases their overall complexity.

Building a basic system which can be subsequently modified into multiple variants for specialized missions results in less complexity than building a single system that attempts to perform a wide range of diverse missions. Thus, the C-130 airframe, which has 40 specialized variants, gets a high S-score, while the multi-role F-22A's S-score is diminished by the bewilderingly large number of components necessary to accomplish all its assigned missions (Air Superiority, Close Air Support, Intelligence, Surveillance, Reconnaissance, etc.) with a single aircraft.

Spinney points out "Increasing complexity is a *cost*…" (Spinney, 1985:6, emphasis in original), so the same simplifying behaviors and decisions which improve a system's S-score might also improve the I-score. Spinney also asserts that "the benefits of increasing complexity are clearly neither self-evident nor clear-cut." (Spinney 1985:85). He points out "reliability is more difficult to predict for complex systems than for simple systems, because complexity increases the uncertainty surrounding interactions between components… Moreover, as the complexity of a weapon increases, its number of failure modes increases." (Spinney, 1985:91). He goes on to ask whether increasing a system's complexity increases or decreases its capability. His conclusion is that "Increasing weapons complexity reduces combat readiness" (Spinney, 1985:11) in the following ways:

- Degrades combat skills by causing inadequate and unrealistic training
- Increases reliability and maintainability problems
- Increases cost of maintenance
- Increases dependence on large vulnerable support base
- Increase economic inefficiency of plans
- Slows modernization by increasing development/procurement lead times
- Multiplies magnitude and likelihood of disaster
- Increases vulnerability to countermeasures
- Cuts forces, supplies and munitions to inadequate numbers

Spinney then rhetorically asks if the "distinctive characteristics generated by weapons complexity compensate for these negative qualities." (Spinney, 1985:11). He points out that "High-complexity aircraft and weapons give up presence (because high cost reduces numbers, and supportability problems reduce sortie rates) in favor of lethality—a quality whose value is maximized in an attrition model [of warfare]." (Spinney, 1985:89). While small numbers of complex, expensive systems may offer superior lethality and thus victory in an attrition model of warfare, Spinney points out "In the American Civil War, World War I and World War II, the winners had more casualties than the losers. At the level of a war outcome, attrition measures would indicate that the winners lost and the losers won." (Spinney, 1985:89). Thus, he argues that a force with small numbers of super-lethal, highly complex weapons is less effective than a force with larger numbers of less expensive, less complex, less lethal weapons.

Building on Col John Boyd's famous "Patterns of Conflict" study, Spinney concludes "*decreasing* complexity in order to diminish friction and 'free up' operations provides the opportunity to magnify the enemy's friction and impede enemy operations." Thus, simplicity not only reduces cost but also creates the possibility of increasing

friction for the opponent. These are all benefits which might be cited by program managers and leaders who hold the Simplicity value.

T: TINY IS GOOD

Finally, the T in FIST stands for Tiny. Unlike the previous three values, Tiny is seldom invoked explicitly, at least not using that particular term. However, Tiny is often practiced and pursued under the labels like lean, streamlined, trim, agile or efficient. Organizations express this value by fielding small teams, using miniaturized components, building small systems or requiring minimal documentation, among other behaviors. When Tiny is not valued, project leaders assemble large teams and large systems, judging the size as a measure of merit.

This piece of the FIST value set was introduced in an article titled "Fist, Part 5" (Quaid & Ward, 2006a). The article explains:

> Tiny is basically the inescapable outcome of the three previous values. If your project is Inexpensive, it has a Tiny budget. If it is Fast, it has a Tiny schedule. A Simple project has a Tiny degree of complexity. Further, a Fast, Inexpensive, and Simple project necessitates a Tiny program office. (Quaid & Ward, 2006a:31)

Because of the current reward and recognition structures in the DoD today, the Tiny value can be particularly difficult to implement. Quaid & Ward illustrate this difficulty when they ask:

> How can we reward smallness when the most prestigious programs a program manager can lead are those with enormous budgets, endless schedules, extreme complexity, and massive teams? How can we reward smallness when a PM's career path is supposed to be one of increasing responsibility, defined as dollars and people managed? (Quaid & Ward, 2006b:32).

Thus, while Tiny can be understood as the cornerstone concept behind the FIST value set, it is perhaps the most difficult to put into practice and the most rare to find.

This is particularly true in environments like the traditional NASA or DoD system development communities, which tend to reward and encourage largeness.

However, given the prominence of Lean development approaches, Agile Acquisitions and Extreme Programming methods, the Tiny value is becoming more popular and common, under a variety of labels. In the 1990's, NASA's Faster, Better, Cheaper initiative deliberately used small teams to build small systems, imitating the success of earlier small teams such as Lockheed's *Skunkworks*. McCurdy points out that "small teams are less expensive to staff than large ones. So long as a project remains simple, small teams also possess an advantage in fighting failure," because, as he explains, "Small teams solve problems informally, a process that becomes more difficult as the team grows in size." (McCurdy, 2001:153). However, a small team's ability to solve problems is degraded by complexity, because as complexity increases, "it quickly outstrips the ability of small teams to manage it." (McCurdy, 2001:153)

McCurdy goes on to praise the virtues of smallness, writing "Smaller spacecraft cost less to construct. Reliability problems on small spacecraft can be resolved through teamwork, which reduces both the scale and the cost of management." (McCurdy, 2001:21). Thus we see the strong interrelations between Tiny, Simple and Inexpensive.

Acquisition Reform efforts over the years often tried to shrink the documentation burden on project leaders, as when the 25 page Lightweight Fighter Request For Proposal limited contractor proposals to 50 pages (Burton, 1993:19). The end result of that effort is now known as the F-16 Fighting Falcon. Perhaps the most explicit expressions of the Tiny value are found in the story of the F-16's development, as when the Falcon's

designer Harry Hillaker said "People think that big is better. It's not." (Hehs, 1991). Statements of value do not get much clearer or emphatic than that.

Defining Project Success

Since this research aims to establish a relationship between the FIST values and successful system development, I need a clear definition of project success. However, as Shenhar, Dvir, Levy and Maltz pointed out, "there is very little agreement in previous studies as to what really constitutes project success. Traditionally, projects were perceived as successful when they met time, budget and performance goals. However, many would agree that there is more to project success than meeting time and budget." (Shenhar, Dvir, Levy, Maltz, 2002:699)

Rather than focus simply on programmatic success (i.e. on-time, on-budget delivery of a system that satisfies the documented requirements) or technological success (i.e. advancing the state of the art), this research examines the *operational* outcome of system development projects. Specifically, success is defined as the degree to which the system achieved/surpassed its functional objectives, met/exceeded its operational requirements, was accepted by the user community and generally changed the world. This is consistent with Suddarth's observation that "For system builders, results come in the form of successfully used products." (Suddarth, 2002:7).

Ironically, whether or not the system was delivered on time or on budget is not necessarily an indication of a successful program, even though budget and schedule are typically the metrics used to assess a program manager's performance (yet another reason this research uses the term *project leader* instead of program manager). However, as the

Air Force Studies Board explained in their assessment of the relationship between systems engineering and defense acquisition program outcomes:

> … programs that succeeded were those that delivered their products within a reasonable margin of the original cost and schedule baseline. Programs that failed, in the committees view, may have delivered successful products but were well outside the reasonable expectations of the original program and were only successful in delivering products after the addition of substantial unplanned funding and a substantial extension of the original schedule. (Air Force Studies Board, 2008:22).

The board's opinion is primarily focused on the concept of *programmatic* instead of operational success, but nonetheless delivering "within a reasonable margin of the original cost and schedule baseline" is one of the factors taken into account in this research when assessing the program's outcome. While delivering on time and on budget does not necessarily ensure operational success, failure to do so can have a strong affect on the system's operational outcome. If a system is delivered too late to be of use (for example, after the war is over), its operational impact on that particular conflict is obviously zero. Similarly, if the system's cost rises to the point that it is not affordable in sufficient quantity, its operational effectiveness is diminished.

Some operational outcomes are clearer cut than others. For example, NASA's X-Ray Timing Explorer's mission was described this way: "The spacecraft was developed, tested and ready for launch several months early, and was completed significantly under the fixed-price budget. It was successfully launched and has met all mission objectives. It is considered a dreamboat by the scientific investigators, who have made many important discoveries." (Laufer, 2000:37). This is clearly an example of an unequivocally positive outcome, both operationally and programmatically.

Another NASA project was described this way "other project managers saw that our experiment worked, learned from it, and adopted the approach for their projects…" (Laufer, 2000:45) Imitation by one's peers is also strong evidence of a positive operational outcome. However, when a story simply concludes "we delivered on time," this is weak evidence of positive operational outcome, and by omitting any reference to the customer's reaction or use of the system, may even be evidence that the system was less than successful in actual operational use.

Focusing on operational rather than simply programmatic outcomes means focusing on the customer, rather than the program manager. This is an important distinction, often missing from the systems engineering and program management literature. I chose to emphasize customer success rather than the program manager's success, because delivering effective systems is supposed to be the ultimate objective of any system development project, particularly those done by the DoD.

In the data analysis portion of this research, the project or organization's operational outcome is compared with their FIST score. All the scores and outcomes are compiled to determine a correlation between the FIST value set and operational outcomes. In the conclusion, the stories and insights are consolidated into heuristics, following the example of Maier and Rechtin's *The Art of Systems Architecting*.

A Note on Trust and Talent

System development program outcomes are determined by the people involved. Successful program managers go out of their way to instead unleash their team's talent rather than dictate and control individual behavior. Very talented people can provide positive results despite bad or inefficient processes, but the best process in the world

cannot fully compensate for a lack of talented people. As Laufer explains, "To cope with conditions of very high speed, coupled with very high technological uncertainty, you must staff your project with highly skilled, dedicated and resourceful people." (Laufer, 2000: 81).

Many other writers and researchers have made and tested these claims, arriving at similar conclusions. A recent and prominent example is the Air Force Research Board, which highlighted "six seeds of failure." In assessing these seeds, the Board's report concluded "… the biggest risk of all in undertaking large development programs is to proceed with less than the best personnel" (Air Force Studies Board, 2008:67). Therefore, this research takes it as axiomatic that organizational success, both operational and programmatic, requires trust and talent and is primarily determined by the people involved. The referenced literature has sufficiently proven this assertion, and no attempt is made in this thesis to re-prove the idea that talent is vitally important and people are an organization's most important asset. In fact, the primacy of people is precisely what makes the question of values so crucial.

FIST and Systems Engineering

Systems engineering is concerned with both technology and organization, the mathematical and the social. In a sense, Systems engineering is the intersection of complex technology and complex organization. Thus, this research applies systems thinking and looks at FIST as both an organizational value set and a design value set, applicable to the entities which design technology projects as well as the technology development projects themselves.

Systems engineers and technology leaders sometimes give the impression that given enough time and money, they can do anything. This does not appear to be true. The Comanche helicopter project spent 21 years and $7B before it was cancelled, having delivered zero aircraft. It is doubtful another decade and a few billion more dollars would have improved the outcome.

This research deconstructs and examines the "we can do anything given enough time and money" component of the systems engineering mythos. It suggests that operational success, in which systems are available when needed and effective when used, is not necessarily ensured by large budgets and long schedules. Indeed, the data shows that excessive amounts of time and money, coupled with a preference for complexity, can lead directly to operational failure. In contrast, small budgets and short timelines seem to have a simulative effect and actually support the goal of delivering an operational system that is available when needed and effective when used.

II. Literature Review

Analyses of the defense acquisition community or NASA's mission development efforts are not hard to find. For several decades, critics of these two groups have echoed some variation of the theme that technology development efforts are too expensive, take too long, are too complicated and too big. It is not a difficult case to make.

The ubiquitous refrain points to a traditional value system within NASA and the DoD that rewards large budgets, long timelines, complex systems and enormous bureaucracies… which leads to programs that overrun and under deliver. Many of these critics offer some variation of the FIST value set as an alternative to the current environment, while others call for more oversight, more formal processes, and stricter bureaucratic or legislative control.

The following books, reports and articles are a brief sample of some of the most prominent and insightful assessments of DoD and NASA system development programs. The majority of the reports are contemporary, but several are historical, indicating that the FIST value set is not a new discovery.

Assessments of Selected Weapon Programs (GAO-08-467SP)

In its sixth annual assessment of selected DoD weapon programs, the GAO bluntly states "cost and schedule outcomes for major weapon programs are not improving over the 6 years we have been issuing this report" (Dodaro, 2008:1), even though "DOD's planned investment for new weapon systems now reflects the highest funding levels in two decades." (Dodaro, 2008:3).

The report highlights disturbing trends in development costs and timelines, and consistently provides explicit support to many of the FIST values. For starters, it points out "A hallmark of an executable program with a sound business case is short development cycle times." (Dodaro, 2008:26) In other words, the GAO affirms that it is important and good to be fast, supporting the Fast value.

The report goes on to explain "Long cycle times promote instability, especially considering DOD's tendency to have changing requirements and program manager turnover. In fact, DOD itself suggests that system development should be limited to about 5 years. *Time-defined constraints such as this are important* because they serve to limit the initial product's requirements, allow for more frequent assimilation of new technologies into weapon systems, and speed new capabilities to the warfighter." (Dodaro, 2008:26). [*emphasis added*].

The report is critical of DoD performance in the area of schedule, pointing out that "on average, the current portfolio of programs has experienced a 21-month delay in delivering initial operational capability to the warfighter." (Dodaro, 2008:8). Clearly, the GAO deems it important and good for development programs to be faster than they are, and is disappointed by the current pace of acquisitions.

On the topic of costs, the report states that "development costs for fiscal year 2007 programs increased by 40 percent from first estimates, compared to 27 percent for fiscal year 2000 programs." (Dodaro, 2008:4). It goes on to say "Total acquisition cost for the current portfolio of major programs under development or in production has grown by nearly $300 billion over initial estimates." (Dodaro, 2008:8). Either the DoD is getting worse at estimation or we are getting worse at controlling costs. In either case, the

cost growth rate is not good. This observation supports the Inexpensive value within the FIST value set.

As for simplicity, the GAO reports "Ninety-six percent of the programs had not met best practice standards for demonstrating mature technologies and design stability before entering the more costly system demonstration phase." (Dodaro, 2008:4) Use of mature technologies and stable designs is a critical component of mature simplicity, as defined in The Simplicity Cycle, so this criticism supports the Simple value.

Complexity (along with its companion size) is frequently cited as a risk-driver in the weapon systems under evaluation, as in the following three examples:

> …development of MUOS ground software represents one of the highest risks to the program due to the size and complexity of the contractor's design. (Dodaro, 2008:144)

> The complexity of the GEO satellites is greater than that of the HEO sensors, and as of September 2007, only 20 percent of planned integration testing on the first satellite was complete. As such, there is high probability that further design flaws may be discovered, leading to more cost and schedule increases. (Dodaro, 2008:154)

> According to program officials, the seeker will be the most challenging technology to demonstrate due to the complexity of the algorithms it will require… (Dodaro, 2008:156)

The report concludes that spending more money and more time on development is not improving acquisition outcomes. The GAO writes "Our analysis does not show any improvements in acquisition outcomes as programs continue to experience increased costs and delays in delivering capabilities to the warfighter. In fact, when compared to the performance of the fiscal year 2000 portfolio of major defense acquisition programs, cost and schedule performance for current programs is actually worse." (Dodaro, 2008:6)

While the report does not assess the size of program offices or the complexity of required processes, it can reasonably be inferred that these Major Defense Acquisition Programs are indeed large, not Tiny.

Better Weapon Program Outcomes Require Discipline, Accountability, and Fundamental Changes in the Acquisition Environment (GAO-08-782T)

This GAO report documents the testimony of Katherine Schinasi, Managing Director of Acquisition and Sourcing Management. It summarizes and draws on the GAO's extensive "body of work on DOD's acquisition, requirements and funding processes, as well as our annual assessment of selected DOD weapon programs." (Schinasi, 2008:1). Thus, it echoes the observations and recommendations of the previously cited GAO report (Dodaro, 2008).

After pointing out that "Congress and DOD have continually explored ways to improve acquisition outcomes without much to show for their efforts," (Schinasi, 2008:1), the report goes on to make several statements bemoaning the fact that the DoD is not implementing the FIST values. Many of the report's statements supporting the FIST values are presented in the negative, criticizing the absence of these values rather than advocating their presence, but the overall effect is to provide support to the importance and goodness of the FIST values.

Specifically, the report states "the requirements and acquisition processes are not agile enough to support programs that can meet current operational requirements." (Schinasi, 2008:2) It is not unreasonable to read this as a statement that the processes are too big and too complex. Smaller, simpler processes would likely provide a greater degree of agility than that found in today's environment.

The report goes on to state "the acquisition environment does not provide appropriate incentives for contractors to stay within cost and schedule targets." (Schinasi, 2008:2) By not incentivizing speed and thrift, the acquisition environment does not hold to the Fast and Inexpensive values. The clear implication is that acquisition outcomes would be improved if the environment supported the idea that it is important and good to be Fast and Inexpensive, and rewarded those behaviors accordingly.

In an earlier testimony to the US Senate, Schinasi clearly highlighted the negative impact of FIST's absence: "In an important sense, success [in DoD acquisitions] has come to mean starting and continuing programs even when cost, schedule, and quantities must be sacrificed." (Schinasi, 2005:4) In other words, it is apparently not important to be Fast or Inexpensive, a situation Schinasi deems unfortunate and inappropriate.

The report points out the negative impact caused by a failure to implement the Fast and Inexpensive values: "Continued cost growth results in less funding being available for other DOD priorities and programs, while continued failure to deliver weapon systems on time delays providing critical capabilities to the warfighter." (Schinasi, 2008:5) These are obvious points, but apparently they need to be stated. The report goes on to explain the importance and benefits of being Fast:

> Constraining development cycles would make it easier to more accurately estimate costs, and as a result, predict the future funding needs and effectively allocate resources. **We have consistently emphasized the need for DOD's weapon programs to establish shorter development cycles**. DOD's conventional acquisition process often requires as many as 10 or 15 years to get from program start to production. Such lengthy cycle times promote program funding instability—especially when considering DOD's tendency to change requirements and funding as well as frequent changes in leadership.
>
> Constraining cycle times to 5 or 6 years would force programs to conduct more detailed systems engineering analyses, lend itself to fully funding programs to

completion, and thereby increase the likelihood that their requirements can be met within established time frames and available resources. An assessment of DOD's acquisition system commissioned by the Deputy Secretary of Defense in 2006 similarly found that **programs should be time-constrained** to reduce pressure on investment accounts and increase funding stability for all programs. (Schinasi, 2008:9) [emphasis added]

The report concludes with an observation that changes to the DoD's organizational values – the statements of priorities and preferences, the artifacts which are deemed important and good and are therefore rewarded – must be at the heart of any effective reform efforts: "Meaningful and lasting reform will not be achieved until DOD changes the acquisition environment and the incentives that drive the behavior of DOD decision makers, the military services, program managers and the defense industry." (Schinasi, 2008:12-13).

Air Force Studies Board Report: Pre-Milestone A and Early Phase Systems Engineering, 2008

This book by the Air Force Studies Board compares the historical timelines and costs of system development with current performance, observing

The time required to execute large, government-sponsored systems development programs has more than doubled over the past 30 years, and the cost growth has been at least as great. Many causes for this trend have been suggested, including the increased complexity of the systems involved; instability of external funding… (AF Studies Board, 2008:14).

By identifying complexity as a potential cause, the Board is perhaps suggesting the Simple value would help improve acquisition outcomes. Indeed, the Board goes on to call out several specific programs, again returning to the idea that complexity contributes to explosive growth in costs and delivery times.

During World War II and the early Cold War, programs such as the Manhattan Project, the Defense Support Program (DSP), the intercontinental ballistic missile, and the U-2 surveillance aircraft all delivered very quickly, generally in fewer than 6 years, first products that today would be described as major systems. Currently, such major programs would likely require 10 to 20 years to complete. System complexity has grown dramatically, and products are not delivered under the same technological, human, and organizational guidelines as before. There has been about a threefold increase in delivery time for most major systems. (AF Studies Board, 2008:14)

The Board identifies "the six seeds of failure," five of which are related to complexity. The only seed not related to complexity is "inexperienced leadership," a concept that resonates with the FIST principle of the importance of talent.

The remaining five complexity-related seeds are "external interface complexity; system complexity; incomplete or unstable requirements at Milestone B; reliance on immature technology; and reliance on large amounts of new software." (AF Studies Board, 2008:67). This list could be simplified by consolidating "interface complexity" and "system complexity" into a single entity called "complexity." Similarly, the distinction between "immature technology" and "new software" is hardly insightful – new software is, by definition, immature. Requirements instability is often the result of confusion caused by excessive complexity. As project leaders become more familiar with the system's complexities, they adjust the requirements accordingly. Simplicity tends to act as a stabilizing force on requirements (as does speed).

The solution to this unfortunate trend towards increased complexity has largely been to implement complex "process improvement" efforts. However, the Board points out:

> … despite the myriad of new and revised processes throughout government acquisition organizations, there is little sign that performance is returning to the development productivity that was achieved decades ago. Indeed, one is tempted

to conclude that performance diminishes as procurement organizations mature and their processes become more complex. (AF Studies Board, 2008:16)

Again, the theme of complexity overwhelming effectiveness is repeated throughout the document. This supports the idea that organizational simplicity, properly understood, is conducive to effective system development projects.

The report also offers an interesting perspective on determining whether a program is successful or not.

> Programs that failed, in the committees view, may have delivered successful products but were well outside the reasonable expectations of the original program and were only successful in delivering products after the addition of substantial unplanned funding and a substantial extension of the original schedule. (AF Studies Board, 2008:26)

This observation has interesting implications for projects like the F-22 and V-22, both of which were only successful "after the addition of substantial unplanned funding" and "substantial extension[s] of the original schedule." The Board seems to be saying that such aircraft should be viewed as failures.

The Board concludes with a number of recommendations which are largely consistent with the FIST values. Along with encouraging the pursuit of simplicity, the Board explicitly supports the Fast value. They write "… the world changes too fast to be friendly to long development cycles. The committee believes that the Air Force should strive to structure major development programs so that initial deployment is achieved within, say 3 to 7 years." (AF Studies Board, 2008:85)

Better, Faster, Cheaper, 2001

In 1992, NASA administrator Daniel Goldin launched the agency's "faster, better, cheaper" (FBC) initiative. The FBC initiative was built on many of the FIST values, to

include simplicity and smallness, both in terms of the technology being developed and the organizations doing the development. The approach of FBC project leaders was quite different than the traditional NASA approach, as McCurdy explains:

> The people who manage "faster, better, cheaper" projects have exactly the same objectives: prevent mission failure while controlling cost and schedule. They attempt to do this, however, in a fundamentally different way. They cannot rely upon elaborate systems management procedures, which are too expensive and time-consuming… Instead, people who run such missions turn to the dynamics that arise in small, cohesive project teams. (McCurdy, 2001:89)

McCurdy identifies 15 techniques used by FBC project leaders. Many of these techniques highlight the organizational values used by NASA on FBC projects, helping to identify and define several measures of merit. These techniques including the following:

- Cost goals. Project leaders accept cost containment (and schedule control) as a major goal.
- Project scale. The spacecraft is small and the project team that develops and flies it is very small.
- Cancellation. Top executives are prepared to cancel any project where cost or schedule spiral out of control, and team members are told that this will happen.
- Risk-taking. Team members are encouraged to be creative and take calculated risks (but told not to fail). (McCurdy, 2001:24-25)

There were a total of 16 FBC projects over the next 8 years, of which 6 failed. This 63% success rate was deemed unacceptable, and the formal FBC initiative was abandoned in 1999 (McCurdy, 2001), despite the initial appreciation that FBC projects are higher risk and therefore had a lower expected success rate. Interestingly, following the $813M Mars Observer failure, NASA did *not* reject the traditional approach or replace their value set, nor did they do so after any number of other costly, high-profile failures. Apparently the consensus among NASA leaders was that they had spent so much

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money on those failed projects that the failure must have an external cause, and therefore internal changes were not needed. The data suggests, however, that the excessive spending rates and the accompanying complexity, both organizational and technical, may have been a contributing factor in the failures.

Despite the lower than expected success rate across the cohort, the Faster, Better, Cheaper approach still has a significant number of proponents and offers some interesting insights into the system development process. Supporters point out that the total cost for the 16 FBC projects was less than the cost of one large planetary expedition. For example, the *Cassini* mission to Saturn cost more, in inflation-adjusted dollars, than all 16 FBC projects, and the 16 projects included "five missions to Mars, one mission to the moon, three space telescopes, two comet and asteroid rendezvous, four Earth-orbiting satellites, and one ion propulsion test vehicle." (McCurdy, 2001:19).

It is also worth considering that nine of the first ten FBC projects were successes, and four of the six failures occurred in 1999. (McCurdy, 2001:2). Perhaps something was happing in 1999 to cause these failures, unrelated to the FBC approach itself.

After studying the entire cohort of FBC missions, McCurdy reached the following conclusion: "Engineers and other experts can reduce the cost of spaceflight and the time necessary to prepare missions for flight. Moreover, they can do so without significant loss of reliability. They can also do so with only modest reductions in spacecraft capability." (McCurdy, 2001:10). Alongside the focus on simplicity, the willingness to make modest reductions in capability is a key aspect of FBC.

It is important to recognize that "better" is a subjective assessment, and according to McCurdy, a "reduced capability does not mean the mission is automatically worse. A

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mission with one-half the capability will be 'better' if it performs that mission at one-tenth the price." (McCurdy, 2001:22). This is a philosophical position, an expression of the organization's values. It is based on the organization's answer to the question "What is good?" Under FBC, a system with reduced capabilities was still considered good if it delivered those capabilities under drastically reduced budgets and timelines. In other words, FBC was a FISTy initiative.

It appears that the problem with FBC is not that it is mathematically correct but operationally incorrect, or "good in theory, bad in practice." Rather, it is a scary theory and requires project leaders to courageously embrace values that run counter to those held by the defenders of the status quo. The FBC approach is therefore not put in practice for reasons having nothing to do with mechanical ease and everything to do with psychological comfort. The key issues revolve around fear, trust, control and organizational values, not any inherent mathematical, technical or financial flaw in the FBC reasoning.

McCurdy points out that "proponents of the approach created failure when they reduced cost and schedule faster than they lessened complexity." (McCurdy, 2001:25), reiterating the concept that simplicity is an essential element in effective FBC technology projects. Attempts were often made to fix a problem by adding additional funds, in the belief that additional spending on redundancies would increase reliability. However, McCurdy points out that "Additional spending does not always purchase added reliability. It buys complexity. Added complexity creates a point of diminishing returns, which eventually reduced reliability." (McCurdy, 2001:155).

McCurdy also points out that "increased spending does not compensate for project that managers developed too rapidly," and goes on to observe that "a project developed too fast and too cheaply will almost certainly develop problems of reliability, but so will one that is simply too fast." (McCurdy, 2001:27) His observations echo this research's previous comments about the danger of speeding.

After highlighting some of the dangers and pitfalls inherent in the FBC approach, McCurdy concludes:

> The 'faster, better, cheaper' approach can overcome problems of reliability. To do so, however, requires close adherence to a number of principles. The designing team must reduce spacecraft size and complexity through micro-technology. Supporters must fund the project at a level commensurate with its complexity. They must provide an adequate development schedule, again based on mission complexity. And they must rigorously utilize team-based management techniques. (McCurdy, 2001:30)

McCurdy's conclusion closely aligns with the FIST model's emphasis on simplicity and smallness, for both the organization and the technology. Reducing complexity allows for shorter development schedules and smaller budgets, while still delivering the required levels of reliability and performance.

NASA's FBC initiative clearly was a value-driven effort, an attempt to present an alternative to the agency's traditional preference for expensive, large, complex, long-term missions. By defining low cost, rapid delivery, simplicity and smallness as measures of merit, NASA explored new possibilities and demonstrated that even for the most difficult mission areas, the FBC approach can deliver. By failing to explicitly include simplicity in that value set, NASA planted the seeds of the initiative's failure.

On The Road Toward Confirming Augustine's Predictions And How To Reverse Course, 2007

This article was published in the Dec 2007 issue of *Defense Acquisition Review Journal*, by Dr. Jan Muczyk, former Dean of the Graduate School of Logistics and Acquisition Management at the Air Force Institute of Technology. Arguing for the operational superiority of large quantities of simple weapon systems over small quantities of complicated "transformational technology," Muczyk writes "quantity has its own quality advantages. However, quantity can only be attained by short product development cycles, and that is only achievable if the Department of Defense relies whenever practicable on an evolutionary approach utilizing low-hanging fruit and off-the-shelf commercial components." (Muczyk, 2007:455).

In other words, Muczyk argues that the DoD should adopt the Fast, Inexpensive and Simple values (and, by implication, the Tiny value as well). The article strongly argues for the importance of rapidly developing low-cost solutions using mature technology – explicitly affirming the F, I and S portions of the FIST model.

On the importance of speed, Muczyk writes "Perhaps the greatest danger associated with lengthy product development cycles is the mission obsolescence of the weapon system before it's even fielded because the facts on the ground change so fast." (Muczyk 2007:458). The article goes on to explain "Future threats will be far less predictable than those during the Cold War era. Consequently, future DoD leaders will have to name that tune after hearing just a few notes, and short cycle times will give them the ability to fashion appropriate and affordable technological responses… we must acquire dominance of product development cycle time in order to maintain our competitive edge on future battlefields." (Muczyk 2007:461).

As for the Inexpensive value, Muczyk offers very strong support of the idea that small budgets are "important and good" – the Inexpensive value. He writes "reducing cost by reducing cycle time is critical," (Muczyk 2007:461) and highlights the interconnectedness of the FIST values by pointing out that "developing weapon systems from low-hanging fruit pretty much guarantees short, less expensive product development cycles." (Muczyk 2007:461) That is, the pursuit of simplicity tends to reduce the amount of time and money required to field a system… and these reductions are desirable.

Taking an approach similar to this thesis, Muczyk examines the operational effectiveness of several historical weapon systems, and ultimately concludes that simpler systems outperform complex ones in actual combat operations. He examines the US bomber inventory (the B-1B, B-2 and B-52), and writes "of the three bomber fleets, given contemporary threats, the B-52 is the most cost-effective to operate, and its standoff weapons probably the most versatile." (Muczyk 2007:456). The more complex and more expensive bombers (B-1 and B-2) are actually less effective than the older, cheaper, simpler B-52.

Muczyk continues his argument that large quantities of simple systems have historically defeated small cohorts of more complex weapons, despite the simpler systems offering inferior individual performance. Looking back to the World War II era, Muczyk points out "The U.S. Sherman tank was inferior in most respects to the German counterparts, but we prevailed with it because we possessed it in massive numbers… The German Me-262 jet fighter, even with its considerable speed advantage, had little bearing on the air war because of its limited numbers. The United States, however, prevailed in

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the air in Europe and in the Pacific because it possessed massive bomber and fighter fleets… In like manner, the German advantage in rocket technology did little to influence the outcome of the war. The much simpler Soviet Katyusha rocket had a much greater impact, in part due to its ubiquitous presence on the battlefield." (Muczyk 2007:460).

The article concludes with a recommendation that the acquisition community embrace the Simple value, specifically in the area of using mature technology rather than relying on new, unproven developments. Muczyk writes "The individual engaged in the oversight must ensure that whenever possible low-hanging technological fruit and off-the-shelf components are incorporated into the weapon system." This pursuit of simplicity, as previously stated, tends to reduce costs and timelines, and enable larger quantities to be purchased and fielded.

Gregory: The Defense Procurement Mess, 1989
This book highlights several aspects of the military technology development quandary, including:

- Overcomplex solutions (Gregory, 1989:2)
- Overmanagement, overregulation, overspecification (Gregory, 1989: 3)
- "Massive paperwork requirement… costing from 25% to more than half of the price of producing weapons." (Gregory, 1989:3)
- Overstaffing (Gregory, 1989:4)
- "Clever but complex contracting methods" (Gregory, 1989:4)
- "… terms of contracts have become exceedingly complex" (Gregory, 1989:4)
- "In trying to create a perfect system, reformers took one from 3-5 years in the 60's to three times longer to do the same job." (Gregory, 1989:8)
- Requirements are overstated (Gregory, 1989:21)
- "In the days before World War II, when aircraft companies were small and the costs of building prototypes were a few thousand, investors could take the gamble…" (Gregory, 1989:72)

- Cost-plus contracts provide contractors with little incentive to minimize costs. (Gregory, 1989:76)

Gregory's rigorous critique addresses the military technology community's preference for "clever but complex" solutions, the lack of incentives to minimize costs or timelines, and the tendency to oversize everything, from staffing to management to regulations and specifications. In a nutshell, Gregory's assessment is that the "mess" is largely the result of a defense procurement environment that is too big, too complicated, too slow, and too expensive, and which seems to perversely value these attributes. These unfortunate values are precisely the opposite of the FIST framework, and they lead to waste, scandal and a loss of credibility for military, government civilians and contractors alike.

In the book's final chapter, titled *Where Do We Go From Here?*, Gregory suggests the acquisition program should simplify and shrink, in order to reduce timelines and costs. He writes:

> The acquisition system must return to the straightforward principles of good, flexible, tight project management [*Simple*]—that is, smaller, dedicated teams [*Tiny*] with responsibility and authority; expeditious decision making [*Fast*]; the replacement of layers of review and oversight [*Simple*] with short, clear chains of command [*Tiny*]. Otherwise, little is in sight to reduce the length of the acquisition cycle—the time to develop and field new weapons—the best and final measure of how well the process is working [*Fast*]. (Gregory, 1989:193-194)

Gregory goes on to advocate shrinking the Office of the Secretary of Defense, reducing the paperwork associated with acquisitions and eliminating layers of bureaucracy and congressional oversight. These recommendations align closely with the FIST value set, and are basically oriented around the "Tiny is good" value, which as we

have seen fosters the adoption of FIST's other three components. Sadly, Gregory's recommendations have not been implemented.

Lessons From The Development of Army Systems, 2008

Published in the July 2008 issue of Defense Acquisition Review Journal, this article examined 13 Army systems and concludes "These data… suggest that it is better to organize and budget projects for shorter time frames whenever possible." In making this conclusion, the authors echo observations from the 1986 Packard Commission, to name but one prominent correlating study.

On their main finding, the authors explain "A central conclusion from this study is that shorter development cycle times favorably correlate with lower levels of… program instability, and with substantially better project outcomes." (Lucas & Rhoades, 2008:115). This is not exactly news to anyone who has been exposed to defense technology development projects, but it is one more piece of statistical evidence supporting the importance of the Fast value. It is indeed good and important to have a short development timeline.

According to Lucas and Rhoads, "stability of program resources, staffing, and objectives is a very powerful influence on the relative success of projects." They go on to point out that "the longer a system stayed in development, the greater chance it had to experience one or more… destabilizing events." (Lucas & Rhoades, 2008:127). Again, the relationship between long projects and increased instability is logically and intuitively obvious, but this article provides statistical research data to support the relationship.

The authors also assessed the level of complexity in each of the 13 systems they investigated, and showed a mild correlation between complexity and the system's ability

to achieve key outcomes. However, development timelines was their main focus, and they primarily discussed complexity in terms of its impact on schedule. Thus, while recognizing that "more complex projects often require longer development cycles and are more likely to experience funding difficulties," the authors conclude their data shows that "duration alone is more strongly related than complexity to the number of successful outcomes." (Lucas & Rhoades, 2008:128). Nonetheless, this data seems to provide a certain amount of support to the importance of the Simple value, as well as evidence of the interrelationship between complexity and development speed.

It is also worth noting that, like this thesis, the article focuses on *operational* outcomes, not programmatic ones, as indicators of developmental success. In fact, the system's performance in the field is the only measure of success used in the article. They write:

> …one of the strongest relationships between development duration and project outcomes is found for how the system performed in the field. Six of the seven systems developed in (about) three years or less met or exceeded expectations when they were deployed in DESERT STORM, compared to only two of six of the longer projects. (Lucas & Rhoades, 2008:128)

Lucas and Rhoades' article shows that "time is not an ally of systems development" (Lucas & Rhoades, 2008:128). In other words, they argue that it is important and good for a system to have a short development timeline, and for project leaders to hold to the Fast value.

Literature Review Conclusion

There is a wide consensus across the books, articles and reports reviewed in the previous pages – many military system development programs cost too much, take too long, are excessively large and excessively complex. The traditionally prescribed

solutions have not been effective, and might even be responsible for making things worse, by requiring complicated, expensive, lengthy process solutions that require massive bureaucracies to implement them. A combination of Theory X management approaches and constantly changing 5-Year Plans simply have not delivered on their promises.

Proposed solutions in the literature tend to revolve around acceleration and simplification – both in terms of the technologies we acquire as well as the bureaucracies that do the acquisitions. Simplicity includes the reliance on people's talents rather than formal process, Theory Y management instead of Theory X, mature technologies instead of unproven new "wonder weapons," quantity instead of quality, small teams instead of large conglomerates, and the systems engineering principle of low-coupling / high-cohesion.

These reports and books do not constitute a perfect prescription for perpetual success. In particular, *Faster, Better, Cheaper* discusses several failed missions, pointing out that the failure-per-attempt rate for a FBC cohort would be higher than under traditional approaches. The failure-per-dollar rate, however, is much better under the FBC approach.

What this body of literature does offer is a combination of statistical and theoretical evidence in support of the concept that the FIST values often lead to positive operational outcomes. It further indicates that the most prominent failures tend to involve perfectionist project leaders rejecting the FIST values and instead viewing complexity and largeness as signs of organizational and technological sophistication.

The literature does not claim the FIST values always will produce successful systems, nor that every failure has its roots in the opposite of the FIST value set.

However, the consensus seems to be that when project leaders reject the FIST value set, the operational outcome is more likely to be negative than positive, while embracing the FIST values tends to lead to reliable, positive operational capabilities.

III. METHODOLOGY

This research seeks to identify the values held by various system development organizations and project teams, for comparison with the operational outcomes of the products produced by those teams. In order to identify the organization's values, I looked for "value clues" in a variety of sources.

Where are value clues found?

Value clues are most easily and often found in the stories told by the members of the organization. Success stories in particular are an excellent way to identify values, because when people brag, they tend to brag about things they value, things they think are important. As they tell their "war stories," expressions of their values naturally rise to the surface.

The term *story* here is used in a general sense, referring to a wide scope of narrative expressions. The stories evaluated in this project include published journal articles, books, case studies, official reports and program briefings, academic case studies, newspaper and magazine articles, and personal interviews.

Selecting The Stories

Each of the 22 projects evaluated in this research was documented in multiple stories, with authors ranging from journalists to project leaders. The specific stories were selected using "theoretical sampling (i.e. cases are chosen for theoretical, not statistical, reasons)," because in this method "random selection is neither necessary, nor even preferable" (Eisenhardt, 1989:537).

Eisenhardt explains "it makes sense to choose cases such as extreme situations and polar types in which the process of interest is 'transparently observable.' Thus, the goal of theoretical sampling is to choose cases which are likely to replicate or extend the emergent theory… This sampling plan was designed to build theories of success and failure." (Eisenhardt, 1989:537). A theory of success and failure is precisely what the FIST research aims to provide.

Eisenhardt and Graebner provide further support for theoretical sampling in a 2007 *Academy of Management Journal* article. Citing a wide range of published articles, they demonstrate the superiority of theoretical sampling over random sampling for case study research: "just as laboratory experiments are not randomly sampled from a population of experiments, but rather, chosen for the likelihood that they will offer theoretical insight, so too are cases sampled for theoretical reasons, such as revelation of an unusual phenomenon, replication of findings from other cases, contrary replication, elimination of alternative explanations, and elaboration of the emergent theory." (Eisnehardt and Graebner, 2007:25).

The theoretical sampling approach is further supported by Schon's description of reflective practice. While the scientific research method, with its focus on theoretical understanding, requires the use of statistical sampling methods and what Schon calls "the logic of confirmation," reflective practice, with its focus on creating practical change, is more readily served by using "the logic of affirmation." (Schon, 1983:155). In this methodology, the sample need not be statistically representative. It simply needs to provide sufficient insight.

This is because the reflective practice approach aims to identify actions (Schon calls them *moves*) which produce satisfactory results. It is not necessary, or even desirable, to ensure the move is a unique or optimal solution, nor that it is based on a *scientifically* robust theory. It is sufficient for the move to produce a *satisfactory* solution, based on a *practically* robust theory.

Schon explains: "Other theories of action or models might also account for the failure of the earlier move and the success of the later one. But in the practice context, priority is placed on the interest in change and therefore on the logic of *affirmation*. It is the logic of affirmation which sets the boundaries of experimental rigor." (Schon, 1983:155). The logic of affirmation basically states "Yes, this move provided a satisfactory confirmation of the hypothesis," but does not rule out the possibility that other moves, based on other hypotheses, could have provided equally satisfactory outcomes (or better!). This is contrary to "the logic of confirmation," which requires ruling out alternative hypotheses and an assurance that the outcome is optimized and unique.

Using the theoretical sampling method, this thesis examines three categories of stories: FIST projects, FIST organizations and non-FIST projects. A FIST project is a single example of the FIST values, while a FIST organization (such as Lockheed's *Skunk Works* division) has a track record of sustained FISTiness. The non-FISTs are projects where FIST values were explicitly rejected, or their opposites were pursued. For each category, I analyze projects with positive and negative outcomes, as defined in a subsequent section.

The stories focused on *system* development projects (i.e. the F-16 Falcon), rather than *technology* development projects (i.e. Low Observable Technology). That is, the stories focused on situations in which a coherent technology system was developed and delivered for an operational use, and did not examine the development of the individual technological components. Basic scientific research projects were also excluded, although many of the NASA stories described the development of systems which were essentially scientific research tools.

The FIST Rubric

Identifying the presence of value clues in a story is necessarily somewhat subjective. Some statements are obvious, such as "We were trying to prove the timeline could be radically reduced from a typical 36-month cycle to 7 months," while other stories are more ambiguous. To deal with this ambiguity, I use a coding scheme known as a rubric to assess the presence or absence of the FIST values.

A rubric is a scoring tool for making subjective assessments. In instructive settings, rubrics are often used by educators to grade essays. In the technology development world, rubrics are used in several maturity models (the Capability Maturity Model, the Service Oriented Architecture Maturity Model, the Enterprise Architecture Maturity Model, etc) to determine an organization's maturity level. The FIST rubric can be thought of as measuring a FIST Maturity Level, referred to as a FIST Score. The rubric is attached in Appendix A and is used to score the stories (written and verbal).

Each component of the FIST model (F, I, S and T) is given a rough numerical score, while the program's operational outcome is given a letter grade (A or F). The initial version of the rubric used a spectrum of grades from A to F, but the distinctions

between A, B and C or between D and F were not meaningful in the context of this research and its emphasis on "extreme cases." The simplified binary distinction between operational success (A) and failure (F) was sufficient for the purpose of this research.

As the research progressed, the rubric was refined to incorporate new insights and observations. Previously scored stories were then rescored, using the updated rubric. This is consistent with the iterative tabulation process described by Eisenhardt (1989:541-544), in which "researchers constantly compare theory and data—iterating toward a theory which closely fits the data," which involves "refining the definition of the construct." (Eisenhardt, 1989:541). As Eisenhardt explains, "This verification process is similar to that in traditional hypothesis testing research," in which experiments are repeated when additional observations are required. (Eisenhardt, 1989:542)

In *The Academy of Management Journal*, Larsson (1993) points out a significant benefit from this method, namely that the research "can be replicated since both their coding schemes [i.e. rubric] and case study reports [i.e. stories] are available to other researchers. Researchers can also apply the coding schemes to other case studies to cross-validate or extend the original findings." (Larsson, 1993:1517). This aspect will be mentioned again in the section recommending further research.

Use Of Co-Evaluators
Several sources (Larsson, 1993:1517; Eisenhardt, 1989: 538) suggest using multiple researchers to cross-validate the scores and provide divergent perspectives. However, since this research is a one-person effort, it was not feasible to have every story assessed by multiple readers. Instead, I recruited additional investigators to apply the rubric to a subset of the stories consisting of 7 systems (approximately 1/3 of the overall

population). The co-investigators are all current or former AFIT students. They are listed below, along with their AFIT degree program and graduation dates:

Maj Steven Behm, System Engineering, March 2009
Maj Garry Haase, System Engineering, March 2009
Capt Gabriel Mounce, Electrical Engineering, March 2003
Capt Peter Mastro, System Engineering, March 2009
Mr. Joseph Simmons, Space Systems Engineering, March 2009

This partial re-sampling aims to enhance confidence in the findings and reduce subjective bias, in accordance with the methodology described by Eisenhardt (1989:538). The volunteer investigators were brought in only after the rubric was stabilized, and their assessments are included in the Data section, following my own assessment.

A Note On Stories: Accuracy Versus Meaning
The stories evaluated in this research are told and written by practitioners and program managers, not professional historians. Each story author has a purpose and a point of view, and often, the purpose has nothing to do with producing an accurate historical record. Thus, the stories analyzed in this thesis may not be dependable as accurate retellings of historical events. This is not problematic, because historical accuracy in the stories is not necessary for the purpose of this research.

That is, a story need not be *factual* to be useful as a source of *value clues*. Indeed, a rigorously researched narrative full of facts and figures might actually be less useful than a more colorful and less historically rigorous telling. For the purposes of this research, the most interesting and relevant aspects might have nothing to do with the historical facts of the case, but rather with the perceptions, priorities, meanings and values expressed in the story.

As O'Neill explains, "The organizational story may lack accuracy, but it does not lack meaning to the recipients…" (O'Neill, 2002:6). O'Neill goes on to explain that a story may be full of "embellishments, omissions and differences between different versions," (O'Neill, 2002: 7), but these do not diminish the story's value. In fact, the inaccuracies may actually be significant indicators and value clues. O'Neill writes "such stories clearly relate organizational values… However, these stories communicate their messages in symbolic, rather than literal form." (O'Neill, 2002:7).

In other words, stories have tremendous value even when their historical, empirical accuracy is in question or unevaluated. Accordingly, in assessing and scoring the stories, no attempt was made to gauge their historical accuracy with regards to various matters of fact. Even obvious embellishments or glaring omissions were useful and potentially full of value clues.

Method Validation

Narrative-based research is increasingly popular in the academic literature, ranging from analysis of formal case studies to more organic, ethnographic story-based approaches. Not surprisingly, there are many ways to investigate and analyze narrative knowledge, and many possible coding schemes for detecting and understanding value clues. I chose a method which is widely used by qualitative researchers, particularly in the field of organizational research.

In *The Academy of Management Review*, Stanford University's Kathleen Eisenhardt published a widely-cited article, which provides "a roadmap for building theories from case study research." (Eisenhardt, 1989:532). Eisenhardt further explains

that "case studies can be used to accomplish various aims," including both testing and generating theories (Eisenhardt, 1989:535).

As previously mentioned, the FIST research project extends the definition of "case study" to include a wide range of organizational and programmatic narratives, a use which is consistent with Eisenhardt's (and others) use of the term.

Eisenhardt's 1989 article includes a table titled *Process of Building Theory from Case Study Research*, a portion of which is reproduced below. These eight steps (and accompanying activities) generally describe this project's methodology:

Table 1: Process of Building Theory from Case Study Research
(Eisenhardt, 1989: 533)

STEP	ACTIVITY
1. Getting Started	Definition of research question Possibly a priori constructs Neither theory nor hypotheses
2. Selecting Cases	Specified population Theoretical, not random sampling
3. Crafting Instruments and Protocols	Multiple data collection methods Qualitative and quantitative data combined Multiple investigators
4. Entering the Field	Overlap data collection and analysis, including field notes Flexible and opportunistic data collection methods
5. Analyzing Data	Within-case analysis Cross-case pattern search using divergent techniques
6. Shaping Hypotheses	Iterative tabulation of evidence for each construct Replication, not sampling, logic across cases Search evidence for "why" behind relationships
7. Enfolding Literature	Comparison with conflicting literature Comparison with similar literature
8. Reaching Closure	Theoretical saturation when possible

This 1989 article is cited over 5,600 times, and Dr. Eisenhardt followed it up with related articles in 1991 and 2007, both of which were also widely cited. The 1991 article expands the concept of multi-case theory building versus single-case theory building,

while the 2007 *Academy of Management Journal* article, co-written with Graebner, cites 35 other researchers to provide additional confirmation of the effectiveness of multiple-case theory building methodology and offer further explanation on specific methods for theoretical sampling. Eisenhardt and Graebner describe the method as "one of the best (if not the best) of the bridges from rich qualitative evidence to mainstream deductive research." (Eisenhardt & Graebner, 2007:25).

Misconceptions on Case Study Use and Methodological Bias

Writing in *Qualitative Inquiry*, Flyvbjerg (2006) corrects several popular misunderstandings about case study research. Two prominent misconceptions are that case study research is only useful for generating hypotheses, but not for testing them, and that case study contains a bias towards verification. The following two conclusions from his article are particularly relevant to this thesis (emphasis added):

1) "The case study is useful for **both** generating and testing of hypothesis." (Flyvbjerg, 2006: 229)

2) "The case study contains **no greater bias** towards verification of the researchers' preconceived notions than other methods of inquiry. On the contrary, experience indicates that the case study contains a greater bias towards falsification of preconceived notions than toward verification." (Flyvbjerg, 2006:237)

On the question of bias, Flyvbjerg cites "the proximity to reality" inherent in case studies—particularly field research and interview-based studies—as "a prerequisite for advanced understanding." (Flyvbjerg, 2006: 236). In fact, his research shows "it is falsification, not verification, that characterizes case study." (Flyvbjerg, 2006: 235).

Citing extensive previous research in this area, he writes, "According to Campbell (1975), Ragin (1992), Geertz (1995), Wieviorka (1992), Flyvbjerg (1998, 2001), and others, researchers who have conducted intensive, in-depth case studies typically report that their preconceived views, assumptions, concepts, and hypotheses were wrong and that the case material has compelled them to revise their hypotheses on essential points." (Flyvbjerg, 2006:235). In other words, case study research is more likely to *challenge* a researcher's a priori bias than to confirm it.

Eisenhardt makes a similar point, explaining the method "tends to 'unfreeze' thinking, and so the process has the potential to generate theory with less researcher bias than theory built from incremental studies or armchair, axiomatic deduction. A second strength is that the emergent theory is likely to be testable with constructs that can be readily measured and hypotheses that can be proven false." (Eisenhardt, 1989: 546-547).

While this method has a documented, demonstrable tendency to falsify, rather than verify, researcher bias, the inherently subjective nature of knowledge is still unavoidable and worth mentioning. However, subjectivity is not necessarily detrimental. In fact, Breuer and Roth argue that "knowledge is… inherently subjective," but they "regard the subjective nature of research as a productive opportunity" (Breuer and Roth, 2003: 5) instead of a detractive risk. They go on to explain that "all actions in research and interactions during the research process can contribute in a positive way to our understanding." (Breuer and Roth, 2003: 11)

So, we have one researcher asserting that case study research tends to disprove biases rather than confirm them, and another pointing out that subjectivity is productive, not detrimental. Taken together, these two principles offer strong support to the

qualitative, subjective, story-based methodology used to produce and test the FIST hypothesis.

IV. Results and Analysis

The Systems

This research encompasses 22 different projects, ranging in time from the World War II era to the present day, and in scope from NASA planetary exploration to USAF aircraft to USMC ground transports to NRO satellite constellations. The scores and outcomes are tabulated in Table 2. The actual data for each system is presented in Appendix C: Story Data.

Table 2: Project Scores And Grades

System Name	F-Score	I-Score	S-Score	T-Score	FIST Score	Outcome
NASA Pathfinder Mission	10	10	10	10	40	A
F-16 Falcon	10	10	10	10	40	A
NASA NEAR Mission	10	10	10	10	40	A
Skunkworks	10	10	10	10	40	A
Pave Low III	10	10	10	10	40	A
P-51 Mustang	10	5	10	10	35	A
F-5 Freedom Fighter	5	10	10	10	35	A
A-10 Thunderbolt	10	10	10	5	35	A
F-20 Tigershark	5	10	10	10	35	F
AD Skyraider	10	5	10	5	30	A
XP-75 Eagle	10	10	5	0	25	F
MRAP	10	0	5	0	15	A
E-3 Sentry (AWACS)	5	0	0	0	5	A
NASA Viking Mission	0	-5	-5	0	-10	A
C-5 Galaxy	0	-5	-5	-5	-15	A
Crusader Artillery	-5	-5	0	-5	-15	F
F-15 Eagle	-5	-5	-5	-5	-20	A
V-22 Osprey	-5	-5	-5	-5	-20	A
F-22 Raptor	-5	-5	-5	-5	-20	F
RH-66 Comanche	-5	-5	-5	-5	-20	F
Future Imagery Architecture	-5	-5	-5	-5	-20	F
Division Air Defense (DIVAD)	-5	-5	-5	-5	-20	F

Figure 3 charts the distribution of FIST scores and grades for the entire data set. Within a given quadrant, the relative position within each grouping is not indicative of differences between systems. That is, the fact that the Pathfinder is at the top of the

column and the P-51 is at the bottom is an artifact of the listing, and does not imply a higher or lower score.
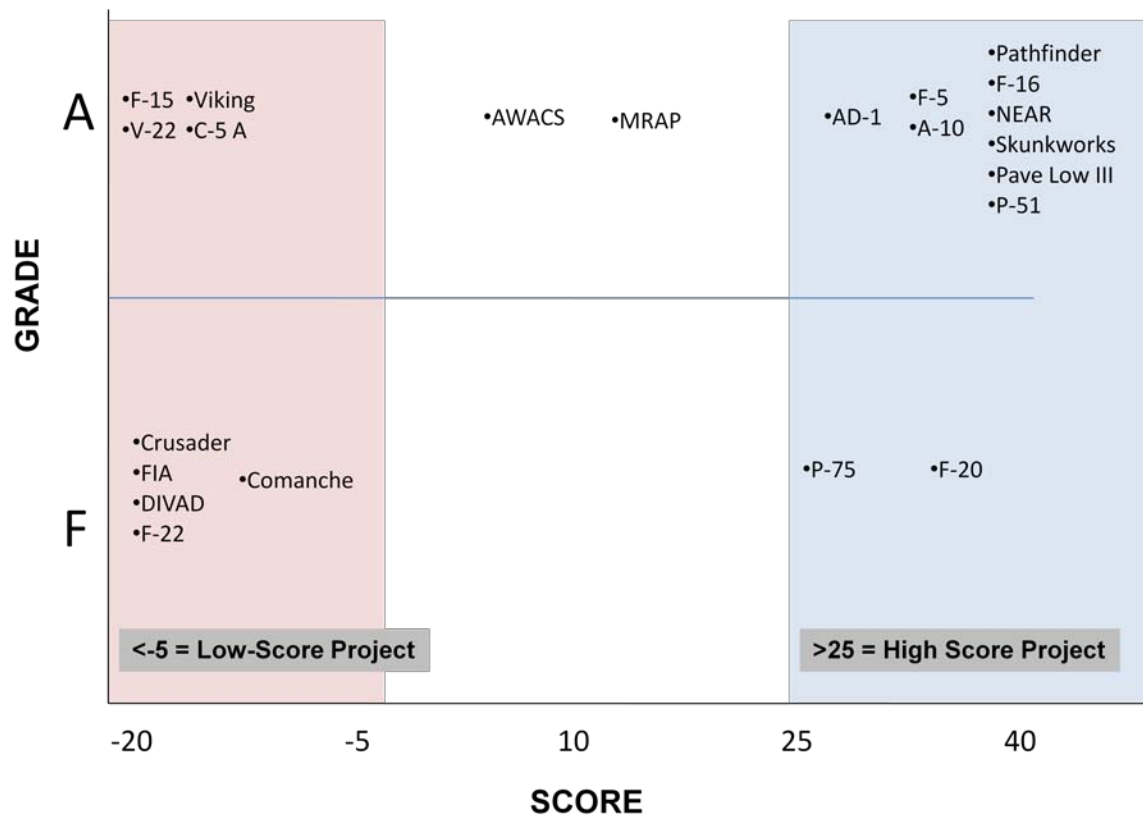
Figure 3: Project Score and Grade Distribution

As discussed in the methodology section, projects were selected using a theoretical sampling approach. Unlike statistical sampling methods, theoretical sampling does not involve collecting a representative sample across the entire field. The objective of theoretical sampling is not to quantify the density of project types and outcomes in a given population. Instead, theoretical sampling allows a researcher to identify boundary cases, to illustrate, highlight and understand various aspects of the hypothesis, theory or subject under examination.

Accordingly, the density of projects in various regions of Figure 3 is not indicative of the statistical distribution of DoD or NASA technology development projects. The relative lack of mid-range scores and grades is similarly an artifact of this research's deliberate predisposition towards extreme projects, and should not be taken as evidence that such mid-range outcomes do not exist. The selection of extreme projects was deliberate and consistent with the methodology guidelines. As Laufer explains, "Excellence [and failure] is a better teacher than mediocrity." (Laufer, 2009).

Figure 3 indicates the existence of both high-score failures and high-score successes in the data sample, as well as low-score failures and low-score successes. That is, all four corners of the chart are populated with at least some systems, which indicates the FIST approach is neither a guarantee of success, nor does it have a monopoly on success. This also shows that the non-FIST approach neither dooms a project to failure nor guarantees a happy ending.

High Score Successes
Projects with a score of 25 or higher on the FIST rubric are designated High Score projects. The 9 successful projects listed below met these criteria:

1. NASA's Pathfinder Mission
2. F-16 Falcon
3. NASA's NEAR Mission
4. Skunkworks
5. Pave Low III
6. P-51 Mustang
7. F-5 Freedom Fighter
8. A-10 Thunderbolt II
9. AD Skyraider

NASA's Pathfinder system is an excellent example of FIST-driven success. Project leaders explicitly affirmed the entire FIST value set, and there was wide

consensus that their emphasis on being fast, inexpensive, simple and tiny directly contributed to the project's overwhelming success.

Lockheed's legendary Skunkworks unit is the prototypical High-Score organization. It has a track record of delivering high-performance, high-impact aircraft on remarkably short timelines and small budgets. They use very simple tools and approaches, and a small team of talented, dedicated personnel, whom they shelter from the traditional bureaucratic requirements and procedures as much as possible.

High Score Failures

High Score failures are those projects which, while achieving a high FIST score, earned an F on the outcome portion of the FIST rubric, indicating a failure to deliver a system which met the users needs or which grossly exceeded the cost and schedule estimates. Two project met these criteria: Northrop's F-20 Tigershark and the WWII P-75 Eagle..

The F-20 Tigershark is an excellent example of a FIST-driven, High Score failure. Not only was the F-20 a failure, the FIST values are very possibly the primary *cause* of the failure. That is, it appears the explicit presence of the FIST values was one of the main reasons for Northrop's failure to sell a single F-20's.

The Tigershark was designed to be an inexpensive, simple export fighter, and Northrop succeeded in achieving that objective. It was marketed as a simple to use, low-cost alternative to advanced jet fighters, suitable for countries which could not handle the costs and complexities of a system like the F-16 (which was originally not available for sale to foreign nations anyway). By taking this approach, Northrop inadvertently planted the seeds of the F-20's destruction.

Northrop's approach might have been effective under the Carter Administration's restrictions on foreign weapon sales, but when the Reagan Administration approved foreign sales of the F-16, the F-20 was widely viewed as a poor substitute. While the Tigershark would likely have been entirely adequate for the defense needs of many smaller countries, the opportunity to own a fleet of F-16's, however unnecessary, was simply too tempting. Buying F-16's was a way for countries to demonstrate that they were serious powers and capable of defending themselves with front-line fighter jets, whether they could actually afford such purchases or not, and regardless of whether the F-20 could have satisfied their actual defense needs. Potential customers derogatorily viewed the F-20 as a "lightweight," (not to be confused with the complimentary designation of the F-16 as a "lightweight fighter" early in its development).

This highlights one of the dangers of using the FIST value set. The FIST values may very well be effective guidelines for efficiently developing effective, reliable technology systems. However, marketing these High Score systems requires synchronization with the customer's values. If a customer views complexity and a high price tag as signs of sophistication, then a High-Score system (such as the F-20) may appear to be a mere toy or an insufficiently effective alternative.

It should be noted that the F-20's testing was limited and its performance was never rigorously tested or proven. The world will never know how good or bad an airframe it was. However, the limited, initial evaluations all indicated the Tigershark was reliable, effective and performed well.

Low Score Projects

Projects with a score of -5 or lower on the FIST rubric are designated Low Score projects. Low Score projects typically exhibited a strong commitment to high-level performance and the inclusion of high technology instead of the FIST values. Project leaders in this category were generally willing to sacrifice cost, schedule, size and simplicity in the pursuit of cutting-edge capabilities.

The 9 projects listed below met these criteria:

1. Viking
2. C-5 Galaxy
3. F-15 Eagle
4. V-22 Osprey
5. F-22 Raptor
6. Crusader Artillery
7. RH-66 Comanche
8. Future Imagery Architecture (FIA)
9. Division Air Defense (DIVAD – aka Sgt. York)

The Low-Score projects ranged from the highly successful C-5A, F-15 and NASA's Viking mission to Mars to the spectacular failures of the Comanche, Crusader and DIVAD.

Low Score Successes

Low Score systems like the F-15 and C-5A successfully provided effective operational capabilities, but typically long after the originally anticipated delivery date, and with a price tag much higher than the initial budget. Project leaders typically emphasized the importance of delivering a cutting-edge technology, which tended to introduce both delays and cost increases. So, while the low-score projects are clearly successful from an operational perspective, their failure to deliver on time and on budget diminishes their value as an exemplar for project leaders to imitate.

NASA's Viking mission to Mars was a resounding success, but its costs effectively prevented NASA from attempting to repeat the mission for two decades. It also reduced the amount of resources available for other projects. Thus, while it was a tactical success for the Viking team, when viewed from the strategic perspective of NASA as a whole, its contribution may be described in significantly less positive terms.

Low Score Failures

When low score projects fail, the cause can generally be found in the counter-productive values expressed by the project leaders. Whether it was a preference for the superficial appearance of programmatic speed, a determination to incorporate bleeding-edge technology, or an overdeveloped fondness for complexity, these values tended to undermine the goal of delivering a system that is "available when needed and effective when used." Often, project leaders take so long to develop the system that it is obsolete before it is delivered, as with the Crusader artillery. Other times the budget swells to insupportable levels, which happened to the Comanche helicopter, or the system gets too complex to be usable, as happened with the DIVAD and FIA projects.

The interviews

The research plan for this project originally included a number of interviews with experienced program managers and project leaders. However, after accomplishing the first few interviews, it was clear the benefits of such an approach were limited and plans for further interviews were abandoned.

Although the interviews were enlightening and enjoyable, they did not produce the kind of data that could be readily incorporated into this research. In the interviews, I was unable to glean a level of granularity and insight equivalent to what I found in the

written stories. The fault had nothing to do with the subjects and everything to do with the interviewer. A more experienced or savvy interviewer would certainly be able to produce a more insightful set of questions and answers.

One interview was a notable exception. A co-evaluator and I sat down with BGen Craig Olson, the Vice Commander of Aeronautical Systems Center. BGen Olson was formerly the Deputy Program Manager and Materiel Wing Director for the V-22 Joint Program Office, and our interview centered on his time working on the V-22. Notes from this interview were incorporated into the V-22 assessment and shed much light on the Osprey's operational effectiveness.

<center>**V. Discussion**</center>

While the FIST value set does not guarantee a positive outcome on every system development project, the data indicates the FIST approach conveys several significant benefits. Specifically, the FIST values enhance project stability, increase the project leader's control and accountability, optimize failure, foster "luck," and facilitate learning. Ultimately, the FIST values seem to support the goal that a system be available when needed and effective when used. Unlike many common measures of programmatic performance, this two-part goal is shared by both project developers and end users alike.

FIST Enhances Project Stability

Project leaders wage a constant battle against instability and uncertainty, whether caused by changes in technology, changes in the environment or changes in the political/financial situation. These changes are often unforeseen and unforseeable, and as Taleb points out, "the unexpected almost always pushes in a single direction: higher costs and a longer time to completion." (Taleb, 2007:157). By pursuing the Fast, Inexpensive, Simple and Tiny values, FIST provides a way for project leaders to inject stability across several fronts.

Fast Stability

Program instability comes from many different sources, but the primary origin for all these sources is simply *time*. Given enough time, new discoveries and breakthroughs will render previous technologies obsolete. Old enemies are defeated while new enemies emerge. Political leaders come and go, as do program managers and project leaders. Economies expand and contract. Each of these changes can cause changes to a project's

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structure, objective, funding, design, priority and schedule. Our inability to accurately predict these changes contributes to the cost and schedule overruns which are so prevalent in DoD and NASA projects. Further complicating matters is the high "impact of forecast degradation over long time periods." (Taleb, 2007:157). Left uncorrected, a small forecasting error's impact grows over time, as shown in Figure 4 below.
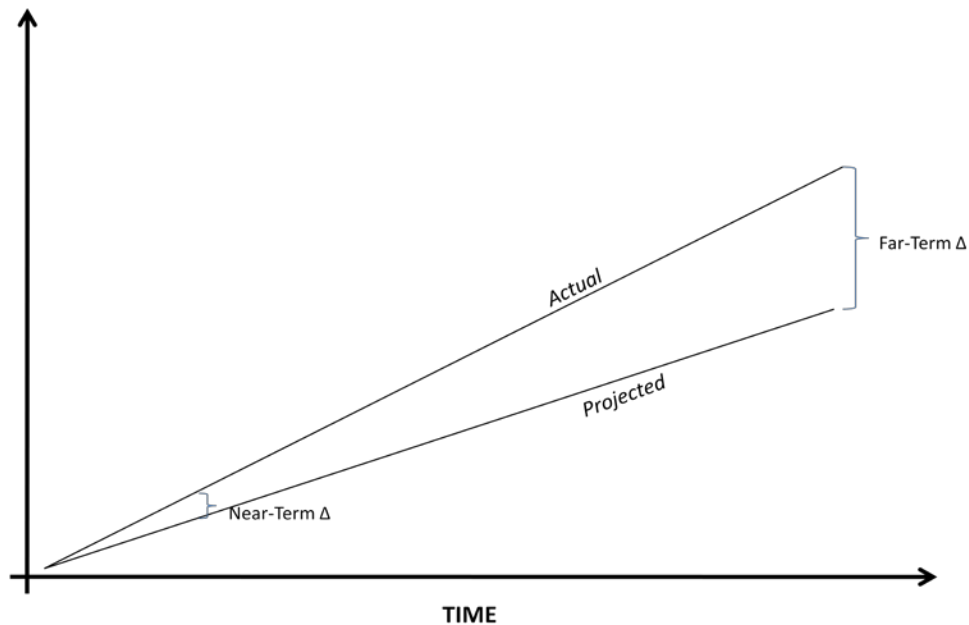
Figure 4: Impact of Error over Time

This notional diagram shows that the near-term delta between actual and projected is much smaller than the far-term delta. The factor under consideration could be cost, schedule, risk or any number of other forecastable items.

The impact of long-term forecast degradation was clearly seen in the F-22 project. During the twenty-six years it spent in development, countless technologies emerged and were replaced, requiring significant, costly and time-consuming modifications to the requirements and design. More significantly, between the project's inception in 1981 and

its IOC in 2005, the Soviet Union collapsed and Al Quaida emerged as America's prime threat, dramatically changing the shape of the threat environment from what was envisioned at the Raptor's inception.

These changes (and many others) increased the F-22's cost, delayed its delivery, shrunk the size of the fleet and stunted its operational effectiveness to the point that for the Raptor has not flown a single combat mission, despite the US being actively engaged in conflicts in both Iraq and Afghanistan for the three years since it went IOC. (Charette, 2008:37)

In contrast to traditional development approaches such as those used on the F-22 program, the FIST approach reduces a project's exposure to the unexpected and minimizes this particular source of instability. Project leaders who embrace the FIST values insist on short timelines and make decisions that support rapid delivery of the required capabilities. By valuing speed, they aim to deliver capabilities before too many changes are manifest. This does not mean all change will be avoided, but both the quantity and significance of the change will be greatly diminished.

Inexpensive Stability

While a short timeline provides a great deal of a FIST project's stability, a small *budget* also conveys stability. This is largely because FISTy projects are not very tempting sources of funds when budget cuts come down the line, for the simple reason that a FIST project's budget is already small. It has essentially been pre-cut, and further decreases to a Tiny budget are likely to be seen as not only unfair but also unproductive and unlikely to make a dent in the organization's overall finances. It simply makes more

sense for budget cutters to go after deeper pockets and projects that are better able to survive a reduction.

The combination of a short timeline and small budget means the project is more likely to be fully funded from the start, rather than having to deal with the uncertainty of requiring budget authorities to authorize future (large) budgets. The near-term delivery schedule also means budget cutters are less likely to cut a current-year budget and promise to "repay" it with future dollars, because the project is potentially slated to deliver before the funds can be repaid.

Finally, new regulations tend to focus on high-profile, big-ticket projects. FISTy projects with sufficiently small budgets can remain appropriately below the radar and thus minimize exposure to the unexpected changes that often accompany new regulations.

Simple Stability

Simplicity also fosters stability, both technically and organizationally. From a technical perspective, the Simple value's emphasis on mature technology tends to reduce the uncertainty and instability inherent in cutting-edge, not-quite-proven technologies. The principle of low coupling / high cohesion, which is also a key technical element of simplicity, means that the impact of change is localized, with limited ripple effect through the rest of the system. Further, a simpler, more streamlined organization tends to have faster and clearer communication than a large, complex organization. This communication clarity reduces the amount of instability caused by miscommunication and bureaucratic inefficiency.

The bottom line is that the FIST values help projects present a smaller target to the forces of change, whether those forces are financial, technical, political, legislative or

some other category. This does not mean FIST makes projects more *resistant* to change – rather, they are simply confronted with fewer instances where change is necessary.

FIST Increases Project Leader's Control And Accountability

Technology systems development efforts typically include a wide range of stakeholders. For the DoD and NASA, these stakeholders include many layers of bureaucracy and several branches of government. Involvement by such an extensive community often limits the amount of influence a project leader can have on the project he or she is responsible for. This is unfortunate because the project leader arguably has the most accurate, relevant and timely information, particularly when compared with individuals who are several layers removed from the project or who are from other organizations entirely. By enhancing the project leader's control, FIST also increases the project leader's accountability for the outcome.

Writing in *Defense Acquisition Review Quarterly*, Christensen, Searle and Vickery examine the question of programmatic influence, drawing an interesting distinction between cost growth and cost overruns on acquisition programs. They define cost growth as "the difference between the *initial* budget and the final cost of the program," while cost overruns are defined as "the difference between a contract's *final* budget and final cost." (Christensen et al, 1999:253-254; emphasis added).

The authors observe that the traditional definition of cost growth fails to make a distinction between factors which a program manager can influence and those factors which are beyond a project leader's scope of influence (i.e. changes in technology, changes in the threat environment, congressional decisions, etc). They suggest project leaders have little influence on cost *growth*, and thus should not be held accountable for it.

Cost *overruns*, on the other hand, derive from factors which project leaders can influence. So, they recommend cost *overruns* as a more appropriate metric for determining programmatic efficiency.

It is indeed important to distinguish between factors a project leader can influence and those that are outside their control, so there is much merit to this argument. However, project leaders actually have more influence over the so-called external factors than Christensen et al seem to think. It is not necessary to simply accept cost growth in an acquisition project as an unavoidable fact of life, unless we also accept decades-long timelines as inevitable and unavoidable. As the previous section explained, by limiting the amount of time spent on a project, FIST gives project leaders the opportunity to minimize many of the destabilizing external forces that lead to cost growth.

The introduction of change from the external environment is beyond the control of the project leader. However, by using a small budget, a short schedule and a streamlined team, FIST minimizes the program's *exposure* to these changes, retaining control, influence and accountability at the local project leader's level instead of allowing external actors to take control of the project. In fact, the project leader's influence is often inversely proportional to the size of the budget and schedule. Nowhere is this seen more starkly than when a project needs to be cancelled.

FIST Projects Are Easier To Cancel
The V-22 Osprey story illustrates an interesting benefit of FIST projects. Specifically, failing projects are easier to kill if they are FISTy instead of big, complex, and expensive.

Secretary of Defense Dick Cheney learned firsthand exactly how difficult it is to cancel a big project that's gone bad. As Time Magazine explained, "… the Osprey proved impossible to kill, thanks to lawmakers who rescued it from [SECDEF] Cheney's ax time and again because of the home-district money that came with it." (Thompson, 2007:1). The Center for Strategic & International Studies put it more bluntly, observing "the V-22 program has nearly 2,000 suppliers in over 40 states, and created jobs in 276 congressional districts." (Cordesman and Kaeser, 2008:26) It is not surprising, therefore, that the Osprey survived multiple attempts by the Secretary of Defense to cancel it.

The simple reality is that big, complex and expensive projects like the V-22 tend to create a lot of jobs, in multiple congressional districts. This is considered good for employment, but it means the DoD is sometimes forced to continue projects it would prefer to cancel. Elevating this kind of decision making ability to the Congressional level effectively reduces the project leader's influence and accountability. The DoD could avoid this problem by not permitting these conditions in the first place.

Congressmen and Senators are appropriately concerned with protecting jobs in their districts and representing the interests of their constituencies. This is what they are elected to do, and such protective actions are entirely consistent with their legitimate responsibilities. However, when the DoD launches a big project, large numbers of jobs are tied to a single system. Cancelling such a system causes pain in many locations, and Congress naturally tries to prevent the negative economic impact. At that point, the DoD, even at the SECDEF level, often finds it difficult or even impossible to cancel the project, even if it is having as many problems as the V-22 was.

In contrast, FIST projects are deliberately too small to spread across a wide range of Congressional districts. By design, FIST projects are developed by Tiny, co-located organizations (which may be part of a larger entity, as with Lockheed Martin's Skunkworks division). When a FIST project begins to go south, it can be cancelled without any given district losing very many jobs, relatively speaking, and before much time has passed. Similarly, the amount of money being spent on any given FIST project is relatively low and is therefore easier to write-off as a research investment, leading to less hand-wringing over waste than the cancellation of a $10 billion project.

Congress is not the problem – they are simply doing what they are elected to do. The problem is the DoD's willingness to pursue big, expensive, complex and lengthy projects. Indeed, a system does not end up with 2,000 suppliers in 40 states by accident. That is very likely a deliberate, cynical attempt to manipulate the system, taking advantage of Congress's legitimate priorities and relying on political pressure to keep a project alive, rather than the project's technical and operational merits.

Projects of all types go bad, and when they do, cancelling them should be an option. It seems logical that the Secretary of Defense should be able to decide whether the military needs a particular system, without being trumped by Congress. Spreading a project across 276 districts makes the system "too popular to be killed" and effectively takes the cancellation option off the table. This leads to excessive spending on projects the DoD does not want, reduces the project leader's influence and accountability, and damages the credibility of the defense acquisition community.

FIST Optimizes Failure

Neither the traditional approach to system development nor the FIST approach guarantees a successful outcome. Given enough attempts, a certain amount of failure is inevitable, regardless of approach. But while we cannot avoid failure entirely, we can influence the kinds of failure we experience. Nicholas Taleb suggests striving to create "situations where favorable consequences are much larger than unfavorable ones," (Taleb, 2007:210). That is, we ought to pursue situations where the benefits of a positive outcome significantly outweigh the cost of a negative outcome. One of the ways to do this is to minimize exposure to loss. The other is to ensure that any negative outcomes become learning experiences and building blocks for future endeavors.

The ideal failure, therefore, is one in which little is lost and much is learned. Such a failure could be termed an *optimal failure*. A *negative failure*, in contrast, is one in which much is lost and little is learned. Table 3 illustrates the differences between optimal failure and negative failure.

Table 3: Failure Types

	Exposure to Loss	**Opportunity to Learn**
Optimal	Low	High
Negative	High	Low

FIST failures tend to be optimal failures. They are discovered before much time and money is expended, so losses are small. They also have a high probability of conveying meaningful lessons, because on a short schedule, project leaders are more easily able to witness the impacts of their decisions and learn from their experience.

Unfortunately, negative failures are arguably the only kind of failure a major defense acquisition program (MDAP) can experience, given the typical MDAP's enormous budget and decades-long schedule. Every time an MDAP fails, it fails spectacularly, costing billions and teaching too little, too late.

Projects below the MDAP threshold can also experience negative failures, given enough years and dollars. Whenever large quantities of time and money are expended before the outcome is observable, the project is exposed to significant loss. If a large percentage of participants have moved on to other projects and/or retired before the failure is observed, the opportunity to learn is low. Even if the original decision makers are still around and directly witness the consequences of their actions, it is often too late to apply the lessons very much further. This is because learning requires both *observation* of the phenomena and *timely reflection followed by action*, neither of which are likely in big, lengthy, expensive projects.

From 1983 to 2004, the US Army spent $7B developing the Comanche helicopter, then cancelled the program and had zero aircraft to show for their troubles. Commenting on the cancellation in Feb 2004, LtGen Richard Cody, deputy chief of staff, G-3, said "If you told me six months ago that I would be standing here saying the Army no longer needs the Comanche helicopter, I wouldn't have believed you." (Merle, 2004) That admirably honest statement highlights the inherent difficulty in learning from experience on a long project, and shows that we really don't know what the lessons will be until the story is finished.

For nearly 21 years, the Army apparently thought things with the Comanche were satisfactory, maybe even worthy of imitation. They didn't have the opportunity to learn

the true lessons of the Comanche until it was cancelled. Until that moment in 2004, there's a good chance the Army was learning – and teaching – the wrong lessons.

The FIST approach requires a significantly different perspective on failure than the standard methodology used on systems like the Comanche. In the traditional approach, it makes sense to measure failure rates on a per-attempt basis (i.e. failures per-cohort or per-portfolio), because each attempt is expensive and takes a long time to realize. But when attempts are quick and inexpensive, as in the FIST approach, a relatively high failure rate is more acceptable, or perhaps even irrelevant. Indeed, a relatively high per-attempt failure rate should perhaps even be demanded. Interestingly, when the FBC initiative began, NASA Administrator Dan Goldin warned against excessively high *success* rates. He told the Jet Propulsion Laboratory's staff "[A] project that's 20 for 20 isn't successful. It's proof that we're playing it too safe." (JPL History – The 90's). Thus, the success rate of the FIST approach is best measured on a per-dollar basis, rather than per-attempt, with some accounting made for the benefits of learning that optimized failures convey.

FIST Enhances Learning

Failure is not the only way to learn, although it is one of the most fruitful. A diverse set of experiences can also help produce agile-minded, well-rounded and creative project leaders. Unfortunately, the traditional development approach, particularly as currently practiced in the field of manned aircraft development, is trending in the opposite direction.

Figure 5 is from a 2005 presentation by senior Lockheed Martin personnel to the Defense Acquisition Performance Assessment Panel (Kubasic & Heath, 2005:4). Using

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data from a 1992 RAND Corp study (Drezner, et al, 1992), it shows that in today's environment, a typical 40-year career span encompasses far fewer military aircraft programs than in generations past. The 17 years since that report was published have confirmed its predictions.

In a similar trend, the number of aerospace companies available to choose from has decreased significantly. For example, in 1970, when the A-10 was being developed, "twelve companies were selected to receive the RFP… six companies responded with proposals." (Jacques & Strouble, 2008:32) Today, the Air Force is basically limited to three: Lockheed-Martin, Boeing and Northrop, and when it comes to building manned jet fighters, these companies are more likely to cooperate than compete, which is a mixed blessing at best.

Figure 5: Declining Experience Levels

This decrease in the number of aircraft being developed (and in the number of aircraft developers) has a negative effect on the industry's overall experience level. As the original RAND study points out:

> An engineer who began his career in the 1950s would have worked in an industry that developed and flew 84 new designs before he retired. An engineer who started in the 1960s will see only 40 new designs fly. The situation gets significantly worse with time. The entry-level designers and engineers in the 1980s and 1990s will be the senior technical and management staff in the 2010s, and their scope and breadth of design experience will fall significantly short of the experience of today's senior technical staff. Furthermore, the future work environment for these engineers will lack the opportunity for cross-fertilization of ideas and knowledge between firms and projects. (Drezner, et al, 1992:48,50)

Unlike the community in the 1950's and 1960's, today's aircraft engineers, program managers and other project leaders have far fewer opportunities to gain experience and perspective, to experiment and learn, or even to talk with other people whose experiences in manned aircraft design diverge from their own. This situation is not limited to aircraft, as many defense related fields are tending towards producing small numbers of big projects rather than large numbers of smaller projects. A similar chart could easily be made for tanks, artillery or naval ships. This reduced exposure to different projects provides limited opportunities to learn, which has a negative impact on the community's overall performance.

However, the situation with UAV's is far different, as Figure 6 shows. In fact, the UAV development environment appears to be the inverse of the manned aircraft situation. The result is a wide range of opportunities for experimentation and learning among

developers, while simultaneously providing innovative, world-class capabilities for the US military across a broad spectrum of operations.
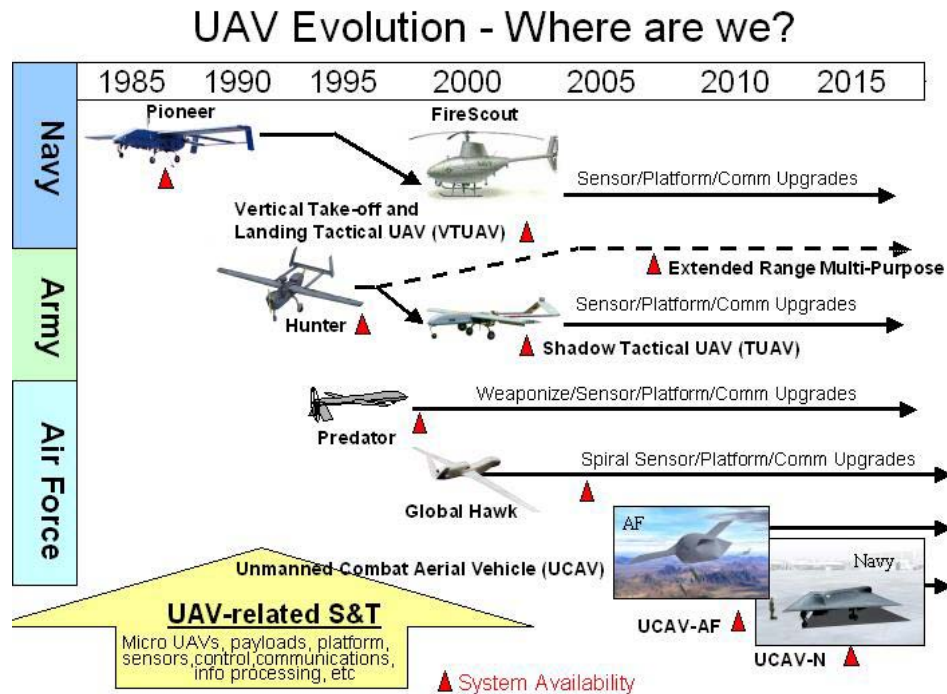
Figure 6: UAV Evolution

The RAND study's concerns about the decrease in new manned aircraft development is therefore partly allayed by the large number of unmanned aircraft currently being developed. This pattern bodes poorly for innovation and growth in manned aircraft, but indicates the future of UAV's is likely to be marked with further breakthrough capabilities and discoveries. Ultimately, the question is not whether there is a body in the cockpit. The question is whether the system provides a dominant capability over our adversaries, and the UAV community is well on its way to demonstrating exactly that.

There are several reasons UAV developers are able to provide such an impressive variety of platforms. The most obvious is the immature state of UAV applications – it is still a relatively new field, with many niches unfilled and opportunities unmet. Unlike the more mature manned fighter or bomber communities (for example), we are still learning what UAV's can do and have not yet fully established their operational boundaries, or even the optimal doctrines to guide their use. A cursory survey of UAV's currently in operation reveals a wide variety of body shapes, sizes, missions, payloads, endurances and capabilities (see for example the UAV's depicted in Figure 6). This diversity is made possible because the underlying technology is relatively low-cost, simple and can be rapidly developed and deployed by small teams. This also fosters competition among developers, which has the potential to convey significant benefits for the DoD in terms of cost, availability and performance.

The aspect of UAV development most relevant to this research is the fact that UAV's are, perhaps uniquely in the history of military technology development, inherently FISTy. That is, when compared to previous systems designed for this mission area (i.e. manned aircraft), modern UAV's are developed on shorter timelines and smaller budgets, are less complex and are much smaller. Individual UAV's may currently be less capable, but since the cost to develop, operate and maintain a UAV is a fraction of a manned aircraft, they can make up that individual operational shortfall by deploying in larger quantities and with more diversity. A sufficiently large fleet of UAV's can outperform manned ISR aircraft (for example), while still costing much less. The inherently FISTy nature of UAV technology is a primary reason for the operational effectiveness of UAV's in Iraq and Afghanistan.

For example, the Army's Shadow UAV has a gross weight of 375 pounds, a 12' wingspan and a $275K pricetag (Shadow 200 Factsheet, GlobalSecurity.org). The Marine Corps' Dragon Eye UAV is even smaller, simpler and less expensive. It weighs in at a mere five pounds, can be assembled in the field in ten minutes and launched by hand. Training a Dragon Eye operator takes less than a week, and $100,000 buys an entire system, including three air vehicles (Barnard Microsystems website). In terms of capability, the Dragon Eye provides "direct threat reduction and reconnaissance" to small Marine units (Dragon Eye Factsheet, GlobalSecurity.org).

FIST Fosters "Luck"

Despite the predictions and prognostications of various analysts (myself included) it is reasonable to assert that program outcomes are to a certain extent the result of unknown, unpredictable, unmeasurable phenomena and hidden forces, which for convenience we can refer to as "luck." Given the centrality of luck in determining program outcomes, one might wonder whether there is a way for project leaders to become luckier.

Professor Richard Wiseman studied the phenomenon of "luck perception and luck production" over a period of ten years (Wiseman, 2003) He concluded that luck, properly defined, is real and can be created. Specifically, his research shows that luck perception and luck production are both related to personality factors such as optimism, extroversion, openness, and low levels of anxiety (Wiseman, 2003). To the extent that such attributes can be learned and practiced, a person can essentially manufacture their own luck.

My colleague Maj Chris Quaid and I examined Wiseman's research in an article titled "Courage, Judgment and Luck," writing:

> Wiseman's research showed that while people who describe themselves as lucky are not more likely to win the lottery, they *are* more likely to experience positive outcomes in other, less random activities. For example, a person's extroversion creates a large social network, which can lead to 'fortuitous' connections with people and resources. Openness to new experiences leads to action, and as John Nash said in *A Beautiful Mind*, "The probability of my success increases with every attempt." (Quaid & Ward 2007:29)

The FIST approach tends to encourage, attract, and reinforce the personality factors Dr. Wiseman identified as components of luck. Starting a program with a short schedule and a tight budget requires optimism. Replacing paperwork with teamwork and formal reviews with informal trust (i.e. simplifying) requires openness, low levels of anxiety and a certain amount of extroversion. The same goes for the FIST emphasis on talent over process.

Taleb made a similar observation to Wiseman, pointing out it is possible to "create luck by sheer exposure" (Taleb, 2007:170). Because the FIST approach involves a large number of small, rapid developments (made possible by lower costs and short schedules), the rate of "sheer exposure" is much higher than in the traditional approach, giving project leaders greater exposure to "the opportunity to be lucky." (Taleb, 2007:222).

Like any effort, FIST is most likely to be successfully implemented by lucky program managers than unlucky ones. However, FIST leads to luck production by fostering openness and extroversion and increasing the exposure rate of new ideas and technologies through rapidly designing, fielding and operating new systems. The traditional approach, in contrast, relies on small numbers of big, expensive, tightly-

controlled, decades-long development projects, which minimizes the possibility of fortuitous discoveries and thus thwarts luck.

Keys To Implementation

There are a number of things project leaders can do to implement the FIST approach, beginning with a recognition that FIST is one unified idea, not four separate ideas. The four components of FIST are connected in many ways, but most prominently by a common thread of simplicity. Accordingly, project leaders should emphasize that value in particular. Second, project leaders need to genuinely understand the values and avoid settling for ineffective imitations such as the mere appearance of speed instead of an actual emphasis on rapid delivery, or simplistic solutions instead of a more profound simplicity. FIST also requires a certain tolerance for failure, so project leaders should expect to pursue multiple iterations. Finally, the FIST value set is most effective if the values are shared by all the stakeholders, so project leaders would do well to discuss the concept with their team, their customers and their suppliers alike.

FIST is One Idea, Not Four

As mentioned in the introduction, the components of the FIST value set cannot be isolated without degrading their ability to contribute to the outcome. Successful application of the FIST approach requires an appreciation of FIST as a single idea, with four internally-consistent and mutually-reinforcing elements, not as a series of independent alternatives for project leaders to weigh against each other in trade-off analyses. This runs counter to the prevailing sense that project leaders must "pick two" from the list of cost, schedule and performance, sacrificing one to deliver the others. The FIST approach suggests that project leaders should "pick all three." Indeed, project

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leaders *must* pick all three if the scheme is to work. An attempt to shorten the schedule without reducing the budget, for example, is likely to result in schedule overruns, which in turn drive cost overruns – a vicious circle not easily broken.

Emphasis on Simplicity

One explanation for the seeming validity of the popular "pick two" heuristic is a failure to address simplicity. Attempts to simultaneously improve cost, schedule and performance without reducing complexity tends to lead to failure, as NASA discovered in the late 1990's. Excessive complexity in the organization and the system virtually *requires* project leaders to improve only two sides of the "Program Manager's Iron Triangle," while simple organizations can produce simple technologies that are simultaneously faster, better and cheaper.

The A-10 is a prime example of a system developed with a healthy appreciation for the central role of simplicity. The project leaders deliberately pursued a simple approach to what was then called the A-X, and "… it was intended that simplicity of design would lead to a shorter development time, lower life cycle cost, reduced maintenance times, increased sortie rates and the ability to operate from austere bases." (Jacques & Strouble, 2008:22)

Simplicity also appears to have a strong direct correlation with operational availability. As Jacques and Strouble point out, "… there was an observed ratio of 3:1 in MMH/FH [Maintenance Man Hours per Flying Hour] between the most complex and the simplest strike aircraft." (Jacques & Strouble, 2008:23) That is, complex aircraft required more maintenance per flight hour than simple aircraft do, which leads to increased availability and decreased costs for simpler aircraft.

The National Reconnaissance Office's FIA project provides a contrary example, and illustrates the danger inherent in pursuing a portion of the FIST value set in isolation rather than incorporating all four components. Anselmo & Butler observe that "FIA… was procured under the faster-better-cheaper mindset of the 1990's," (Anselmo & Butler, 2005:2). Early reports describe the project in terms of using smaller, cheaper satellites, a concept that project leaders never apparently bought in to and which they quickly abandoned. While FIA was ostensibly an attempt to apply the Faster, Better, Cheaper approach, project leaders were clearly committed from the start to developing a system that was tremendously complex. The failure to reduce complexity lead to the project's eventual (one might say inevitable) failure.

The danger introduced by complexity was not unforeseen, as the following references illustrate:

> "… an internal assessment that questioned whether its lofty technological goals were attainable given the tight budget and schedule." (Taubman, 2007:2)

> "The satellites were loaded with intelligence collection requirements, as numerous intelligence and military services competed to influence the design. Boeing's initial design for the optical system that was the heart of one of the two new satellite systems was so elaborate that optical engineers working on the project said it could not be built." (Taubman, 2007:2)

> "… outside engineers questioned the photo satellite's intricate optical system… it soon became clear the system could not be built." (Taubman, 2007:8-9)

> "… the government's addition of more stringent requirements, the new satellites are looking more like the 'Battlestar Galacticas' they were supposed to replace than the simple spacecraft envisioned in 1999." (Anselmo & Butler, 2005:1)

The initial desire to be "faster, better, cheaper," was directly undercut by the preference for complexity on the part of both the government and contractors. By pursuing complexity instead of simplicity, project leaders surrendered any benefits that

might have been conveyed by the Fast or Inexpensive values. They also forsook the ability to express the Tiny value.

The cover story in Time Magazine's March 7, 1983 issue paints a similar picture. In this report, a preference for complexity gets much of the blame for a variety of failed military technology projects. Quoting a Heritage Foundation report, the article points out "The evidence suggests that complex technology is usually relatively ineffective." (Isaacson, 1983:4). It also cites Spinney's 1980 *Defense Facts of Life* report, which it says "argued that the pursuit of complex technology has resulted in the production of weapons that are high in cost, few in number and questionable in effectiveness." (Isaacson, 1983:3).

The article supports the position of reformers who "argue that in many cases the simpler weapons are actually more effective." (Isaacson, 1983:7). The article goes on to suggest that "whether a weapon can be afforded in adequate numbers should be a more important concern than whether it is state-of-the-art…" (Isaacson, 1983:12). This aligns with the idea that the FIST values must be used in concert, and cannot be implemented piecemeal.

Use Mature Technologies
One of the common themes among FIST projects is the use of mature technologies. This suggests that where mature technology is not available, the FIST approach may not be advisable. Alternately, one may posit that mature technology is almost always available, and project leaders need only resist the temptation to stake their outcome on a hoped-for-but-currently-unavailable future technology.

Throughout this research, a preference for mature technology is most often linked to the Simple value, but because the FIST values are interrelated, using mature technologies can also be an expression of the Fast, Inexpensive and Tiny values.

When it is important and good for a project to be Fast and Inexpensive, mature technologies are an obvious choice. The costs associated with mature technologies are more likely to be known and documented than those associated with new technologies, making cost estimations easier and more reliable. Using proven technologies can also save time and money by allowing project leaders to minimize R&D, testing and experimentation.

The XP-75 Eagle and the DIVAD programs both illustrate some of the pitfalls inherent in using mature technology. The DIVAD's selection of inappropriate components has already been discussed. The XP-75 did much the same thing, and encountered very similar issues. Many of the off-the-shelf components were found to be inadequate once they were integrated into the airframe, and required a significant amount of rework. This greatly reduced the anticipated benefit of using existing components, as the following quotes show:

> "By enlarging the tail surface, most of the apparent instability could be overcome, but this meant it would no longer be possible to use the ready-built, off-the-shelf stock design already in production…" (Holley, 1987:590)

> "To make matters worse, the Allison engine, which had been rushed into production before it was thoroughly debugged, was not performing up to expectations…" (Holley, 1987:590)

> "The remedy, eventually devised, was to extend the ailerons out to the wingtips to insure greater stability and control. But this, too, required reworking the standard ready-built wings…" (Holley, 1987:590)

> "… more and more evidence emerged to indict the whole scheme to use off-the-shelf stock components to build a superior high-performance aircraft." (Holley, 1987:591)

Recall from the earlier discussion on the Fast value that valuing speed does not dictate a specific development timeline. Thus, when a project leader borrows technology from a project that has been in development for 20 years, at a cost of billions of dollars, this does not disprove the presence of the Fast and Inexpensive values for that system. In fact, leveraging old money and existing technology to build a new system rather than spending new money to develop new technology is often an explicit expression of the FIST values.

A common short cut for delivering operationally effective systems is to "start before you start," taking advantage of existing research, knowledge, technologies and systems, and integrating them in new and interesting ways to deliver the needed capabilities. Technological breakthroughs and scientific discoveries often take decades to accomplish and can rarely be accomplished according to a program manager's schedule. Thus, it makes sense to rely on breakthroughs and discoveries that have already been made, rather than hope one will be made in time to be useful. In fact, the secret behind most of the "airplane designed in a hotel room over the weekend" stories (e.g. the P-75, B-52, etc) is that the designers were not starting from scratch.

Avoid Imitations

FIST works best when the FIST values are deeply understood and held, not treated as window dressing or a simplistic quick-fix. Like most approaches to organizational behavior, the FIST approach can be easily undermined by project leaders who are not committed to the principles involved or who do not fully understand them. The Army's DIVAD program is an excellent example of project leaders settling for a superficial appearance of the FIST values, rather than actually expressing them.

At first glance, DIVAD had all the appearances of a FIST project, with frequent assertions in support of several of the FIST values and many instances of contractual, procedural and technical decisions being made based on a desire to cut cost and schedule. For example, the contractor was given the flexibility to trade-off requirements for cost and schedule savings, which seems to indicate that Fast and Inexpensive mattered more than high-technology or performance. However, upon closer examination, this project is revealed to be a pseudo-FIST effort, with a significant emphasis on *appearing* to be fast and inexpensive, rather than actually embracing or understanding how to apply these values.

One commentator pointed that "… greater priority has been given to adhering to the schedule than to correcting some serious system performance problems at this time." (Ditton, 1988:8). Another observed that "…calendar schedule compliance had a higher priority than test matrix completion… the combination of these factors precluded complete execution of the test plan." (Adam, 1987:33)

The project leaders' determination to avoid a schedule slip led them to ignore serious system performance problems. While the team achieved a high degree of "*calendar* schedule compliance," one might ask what it means to be on schedule if the system does not actually do what it needs to do by the delivery date. A project that fails to meet the critical performance requirements by the necessary date cannot be considered "on schedule" in anything more than a superficial sense.

Similarly, the literature asserts that project leaders "successfully controlled costs" on the DIVAD development, but this is not an accurate statement. Project leaders merely

controlled *spending*, not cost. That is, they spent as much as they'd planned to spend in the time allotted, but they purchased far less than their customers needed, and the DIVAD's performance suffered accordingly. By purchasing less, they were not genuinely expressing the Inexpensive value. They simply settled for the illusion of Inexpensive, with disastrous results. The truth is, they paid a lot and got very little, in large part because their decisions were not consistent with the Inexpensive value.

Much is made of the Army's decision to simplify the procurement process, freeing Ford from the complexities of government regulation and requirements. However, the Army's "hands off" policy was unfortunately accompanied by an "eyes shut and ears plugged" approach, creating the appearance of simplifying the situation in the short term, while actually making things more complicated down the road. There is a difference between not interfering with the contractor's decisions and not really being aware of them, a distinction the DIVAD project leaders did not seem to grasp. Simply handing a contract to a company and asking them to report back when the job is complete is not simple – it is simplistic.

Further complicating things was the DIVAD's attempt to use mature technologies. Ditton explains "… the DIVAD gun system was supposed to be an integration of proven major components, including the M-48A5 tank chassis, twin Swedish Bofors 40 millimeter guns, and radars from the F-16 fighter." (Ditton, 1988:4) This is only an expression of the Simple value if project leaders select mature technologies that actually perform the required functions. Sadly, the DIVAD project leaders made several unfortunate selections.

"…Although each major subsystem was a proven component, the sum of the components could not match contract requirements, much less battlefield reality. The F-16 radar operates on detection of movement and was successful at acquiring moving targets. Unfortunately, it had difficulty acquiring stationary targets." (Ditton, 1988:6)

Thus, the decision to incorporate mature technology had the *appearance* of simplicity, but not the substance. The F-16 radar was only good at detecting *moving* targets, while the DIVAD needed to acquire *stationary* ones. Similarly, the DIVAD was built on an existing tank chassis, which would have made sense if that chassis had been powerful enough to haul the DIVAD's full weight. In fact, "the M-48's 750-horsepower engine was designed to power a 50-ton tank, not the 60-ton Sergeant York vehicle." (Adam, 1987:32) Since the DIVAD's weight exceeded the engine's designed capacity by 20%, one might argue that the M-48, while mature, for this purpose was neither proven nor appropriate. The Secretary of Defense canceled the DIVAD project on August 27, 1985.

The lesson from the DIVAD is clear – superficial expressions of the FIST values are not adequate. There is a significant difference between being Fast, Inexpensive and Simple, and merely being Hasty, Cheap and Simplistic. Adhering to a project's schedule or budget is meaningless if the necessary requirements are not satisfied by the expenditure, and mature technologies are only good if they perform the required functions. In order to genuinely use the FIST approach, project leaders must deeply understand the value set and how to properly express it.

Iterate (aka Expect, Understand and Value Failures)

The FIST approach is most successful when done iteratively; it is most risky when done as a one-shot deal. The development of the XP-75 Eagle during World War II clearly illustrates this principle:

> "In September 1941, the corporation [General Motors] approached Maj Gen O.P. Echols, the commanding general of Materiel Command, with a proposal to develop a fighter aircraft in a remarkably short time by using, as far as possible, structures, controls, and accessories already in full production for other aircraft in order to obviate the need for long delays in tooling up for production." (Holley, 1987:587)

General Arnold, the commanding general of the Army Air Forces, quickly made it clear that the project leaders had to get things right the first time, demanding that the initial experiment meet the full requirements. "'If it does not meet our requirements,' he wrote, 'all orders may be cancelled; everyone must understand this.'" (Holley, 1987:589)

As it turned out, the initial experiment showed a lot of promise, but was not a complete success. Accordingly, "On October 4, 1944, the chief of air staff, Lt. Gen. B.M. Giles, signed the order terminating the contract." (Holley, 1987:591) It is unknown whether subsequent attempts would have led to better outcomes, but we cannot rule out the possibility.

Expecting the initial version of experimental aircraft to perform well and meet all the requirements is not consistent with the FIST approach. This preference for immediate perfection raises the importance of performance ahead of timeline or budget, thus diminishing the role of the FIST values. It also overlooks the fact that each attempt is made with minimal exposure to loss. Using FIST, project leaders should plan on iterative deliveries of systems, with increasing degrees of capability and reliability in each iteration.

Establish Shared Values

The FIST approach to system development is most effective when the developers and the customers are operating from a shared set of values, and are in agreement as to the measures of merit for the proposed system. Northrop learned this lesson painfully on the F-20 Tigershark project.

Following their success with the F-5, Northrop explicitly focused on building a FISTy aircraft: the F-20 Tigershark. It was intended for sale to foreign nations, and was designed to be an appealing alternative to the downgraded versions of the F-16 Falcon approved for foreign sale under the Carter administration's policies.

In 1981, the Reagan administration changed the policy, forcing the F-20 to compete against the fully-configured F-16, instead of against the degraded version. As soon as foreign buyers had the option to purchase the F-16, the F-20's appeal was much diminished.

Martin & Schmidt point out, "Now that F-16A's had been sold to Venezuela and Pakistan, most developing countries began requesting similar aircraft, regardless of their budgets or realistic assessments of their security threats." (Martin & Schmidt, 1987:14-15). Rather than base their purchase decision on an assessment of the actual threat environments they faced, foreign governments preferred the larger, more expensive, more complex F-16, and they "demanded the highest level of technology they could acquire." (Martin & Schmidt, 1987:21).

This was a psychological and emotional decision on the part of foreign governments, based on a desire to appear fully modern and tough. Rather than valuing the F-20's simplicity, availability and low cost, they preferred the F-16's relative complexity,

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higher costs and greater performance. It should be pointed out that much the same decision process goes on in the US as well, so they were only following the DoD's example. In the end, the very values which led to the development of the Tigershark as a simple, reliable, low-cost fighter jet actually undercut its marketability, because these values were not shared by the potential customers.

Northrop was not able to sell even a single F-20. The Tigershark's limited performance was certainly a contributing factor, as was the change in US policy on weapon exports. However, the primary reason appears to be the striking mismatch between Northrop's design values and the values of its potential clients.

FIST Values / American Values
Value statements are cultural artifacts, and the American defense community has a well established set of values that help to define its culture. Tobias et al point out that "Most Americans subscribe to the notion that 'You get what you pay for'; that the more expensive a weapon is, the better it is. If it can do more—fly higher or drive faster—it must be better. The Pentagon, too, is inclined in this direction." (Tobias et al, 1982:366).

Thus, it might seem the FIST value set, with its emphasis on small, simple and inexpensive technologies, is fundamentally at odds with America's and the DoD's cultural values. That is apparently often the case, as Tobias et al pointed out: "What does our weaponry and style of warfare say about us? As we have already noted, we often build weapons that are on the frontiers of their technology: complex, sophisticated and expensive… [and we] view technological innovation as the decisive factor in victory." (Tobias et al, 1982:382). The authors also point out the DoD's "goal is to maximize

performance, often with little regard for cost," (Tobias et al, 1982:260), then further highlight the distance between the DoD's values and the FIST values:

> We are a society that places a high value on the lives of our soldiers and we would rather expend equipment and materiel, however costly, than lives. In Vietnam our lavish use of exotic weapons, airpower, and firepower reflected this and contributed mightily to the dollar cost of the war… we design and build weapons with an eye toward the creature comforts of their crews. This partly accounts for the larger size and higher cost of our warships and tanks, for example, in comparison to those of the Soviets, who give physical comfort a much lower priority. (Tobias et al, 1982:383)

In other words, according to Tobias et al, the DoD considers many other factors, including physical comfort, to be more important than low-cost, rapid development, simplicity or smallness. While Tobias et al were writing in 1982, little has changed in the DoD's value structure since that time.

However, it is not clear the American pursuit of big, expensive, complex and comfortable systems actually enhances survivability, reliability, combat effectiveness, availability or other measures of operational outcome. In fact, these traditional, non-FIST values might actually put more American lives at risk, not to mention our overall defense posture, military capabilities and national economic health. Tobias et al point out, "… we get the weapons we deserve: the product of our infatuation with gadgets, our optimism, and our extravagance. But in another sense we may not be getting the weapons we need." (Tobias et al, 1982:383)

While this research turned up many examples of big, expensive, complex systems that performed well, it is not clear the non-FIST approach leads to optimal outcomes. It is entirely possible that equivalent performance could have been achieved on those projects with a smaller investment of time and money, had such an approach been attempted. It is

also observed that large budgets and endless schedules lead to negative outcomes with depressing regularity.

Tobias et al also point out that when we examine the history of weapons and warfare, we "find lots of examples of weapons that were cheap and successful, 'winners,' and others that were expensive and unsuccessful, 'losers.'" (Tobias et al, 1982:366). In the 27 years since their book was published, the *cheap winner / expensive loser* pattern has clearly continued.

Interestingly, Tobias et al also observe that America's "reliance on technology is relatively new, by and large a post-World War II phenomenon. In the past, we relied instead on large quantities of dependable but conservatively designed weapons that could be operated by quickly trained troops." (Tobias et al, 1982:382). This description of American design values lines up closely with the FIST model and echoes the values evident in the Soviet T-34 tank, which performed so admirably against the German Panzer IV's in World War II. Indeed, America's pre-World War II era, with its emphasis on FIST design values, has an impressive track record of operational effectiveness.

The pre-World War II era was not the last group of Americans to embrace the FIST values. As my research data shows, small groups, at many times throughout recent history, have accepted and applied these values to great effect.

In the 1970's and 1980's, a group known as The Fighter Mafia led the development of several aircraft, including the F-16 and A-10. As Burton explains, the Figher Mafia's "philosophy is easily stated: Technology can be used to produce simpler, hence lower-cost weapons; lower-cost weapons can permit larger forces… The reformers were concerned about complexity, cost and combat usefulness, not 'high' or 'low'

technology." (Burton 1993: 26-27). In discussing the development of the A-10, Burton

writes "The reformers preferred eyeballs as primary sensors in finding tanks and the use

of inexpensive cannon in killing them." (Burton 1993:26)

Col James Burton, one of the Fighter Mafia reformers, even proposed the Air

Force develop a new airplane, which he named the Blitzfighter. He writes:

> I prepared an advocacy briefing that called for the development of a small, simple, lethal, and relatively cheap airplane that would be designed solely for close support of the ground troops… I wanted an airplane in the 5,000- to 10,000-pound class (one-tenth the weight of the Enhanced Tactical Fighter), one smaller than any combat airplane in the inventory (one-fourth the size of the A-10), and one that cost less than $2 million. At this price, we could flood the battlefield with swarms of airplanes.

> The airplane would be designed around a four-barrel version of the same cannon that was in production on the A-10, which used a seven-barrel cannon that fired shells costing only $13 apiece… The Blitzfighter would have no high-tech bells and whistles and no wonder weapons… With the ability to operate from grass fields, the Blitzfighter did not demand fixed, expensive airfields that probably would cease to exist ten minutes after a war started… (Burton 1993:57-58)

This concept is a clear sign of the FIST values at work. Burton's envisioned

Blitzfighter was never built, apparently because Burton's superiors did not share his

values—which is one of the pitfalls inherent in attempting to use the FIST values. When

they are not shared by one's customers or superiors, the result is seldom acceptable or

successful. Northrop learned this lesson the hard way on the F-20 program, and Burton

learned it many times over.

The FIST Heuristics

> *…there need to be more general heuristics to help guide those involved in this growth industry [systems architecting].* (Wieser, et al, 2006:44).

Program management and systems engineering are largely social disciplines, not hard sciences. They involve subjective questions of morale, opinion, values and other intangibles, and their secrets are generally not revealed through statistical analysis, however complex. Attempts to treat system development methodologies as optimizable mathematical operations are inappropriate and tend to produce unhelpful solutions or irrelevant insights, based on an illusion of rationality.

To borrow a phrase from Nicholas Taleb, the mathematical approach treats program management like "a second-rate engineering problem for those who want to pretend that they are in the physics department." (Taleb, 2007:184). The truth is, systems engineers do not primarily deal with questions of physics, and systems engineering (particularly in the DoD and NASA) is not strictly an engineering problem. A systems engineer's tool kit should include general guidelines and principles, and not solely rely on formal rules and equations.

Disciplines like systems engineering, systems architecture and program management, in which practitioners confront complex problems and unique situations, often rely on *heuristics*, which Maier and Rechtin describe as "trusted, non-analytic guidelines for treating complex, inherently unbounded, ill-structured problems." (Maier & Rechtin, 2000:26) Accordingly, the conclusions of this research are summarized, not in a statistical table, but as a collection of heuristics. These rules of thumb are intended to illuminate facets of the systems engineering art, to guide system developers, to encourage "reflective practice," and to offer memorable summaries of reliable principles.

Heuristics are general principles, not hard-and-fast rules. They should be understood as vectors, not boundaries, and treated as suggestions, not commands. Like zen *koans*, they are for pondering, for thoughtful consideration and experimentation. It is important to bear in mind that the heuristics listed below are "not proven by the stories, but are designed to be general truths that are illustrated by the stories." (Laufer, 2000:xx)

The objective of this list is to expand what Schön calls the practitioner's "*repertoire* of examples, images, understandings and actions." (Schön, 1983:138, emphasis in original). Under Schön's methodology, practitioners use their repertoire to understand unfamiliar problems in terms of familiar ones, and unsolved problems in terms of solved ones. Expanding the repertoire puts more tools at the practitioner's disposal, enabling the community so understand and solve problems which were previously unfamiliar or unsolved.

Table 4: FIST Heuristics

1. Spending less time gives you more time.
2. To finish early, start early.
3. The tortoise was faster than the hare.
4. The distance between planning and execution should be as short as possible (i.e. if you wait to the last minute, it only takes a minute – so take the minute now.)
5. If I don't have enough money, don't give me more time.
6. The best way to run a program is quickly. (Gregory, 1985:162)
7. The best way to unleash talent is not to have too much of it.
8. Talent trumps process.
9. Generalize the people, specialize the tools (the Batman Principle).
10. You can't make a discovery according to a schedule.
11. Don't deal with complexity by adding more complexity. Deal with complexity by removing it.
12. Worse is better (aka the best is the enemy of the good enough).
13. Theory Y management is simpler than Theory X.

14. Complexity and reliability are inversely proportional.

15. Only ask for one miracle per program. (Rep. Heather Wilson, House Intelligence Committee)

16. Don't tinker – it increases complexity, costs time, costs money, introduces instability.

17. Increasing complexity is a cost. (Spinney, 1993:3)

18. Better, faster, cheaper – if you pick two, you'll only get two.

19. Better, faster, cheaper – pick three.

20. The project leader's influence over the development is inversely proportional to the budget and schedule.

21. FIST failures are optimized failures.

One item on the list is of particular personal interest and worth a brief sidebar. In 1999, the apparent failure of NASA's Faster, Better, Cheaper initiative helped popularize the heuristic "*faster, better, cheaper, pick two*." One of this research project's objectives was to examine this heuristic and see to what extent it is a reliable guideline. The data indicates the "pick two" approach is unnecessary at best and a counter-productive self-fulfilling prophecy at worst. Several of the referenced projects demonstrated the possibility of delivering a project that is simultaneously fast, inexpensive, simple and tiny, while still providing end users with top-shelf performance and reliability.

When a project leader decides to make tradeoffs between cost, schedule and performance, focusing on two while sacrificing the third, demonstrable improvements are often made in two areas, to the detriment of the third. However, it need not be this way. When project leaders refuse to sacrifice any of the three, and view cost, schedule and performance as not only interrelated but also internally reinforcing, improvements in all three areas can be achieved simultaneously. Project leaders can safely reject the "pick

two" heuristic, on the grounds that it needlessly degrades the program manager's performance as well as the performance of the developed system.

Recommendations For Further Research

This thesis explored the relationship between organizational values and operational performance of system development projects, primarily focusing on spacecraft and military aircraft. These two technology categories were selected for several reasons – they are high-profile, well documented, and often troubled. They are also strikingly expensive, and thus offer an opportunity to save a significant amount of money by improving the outcomes.

Each story highlighted a different aspect of the relationship between the FIST values and operational outcomes. Future researchers may want to apply the FIST rubric to system development projects I did not examine, such as the Navy's F-14 and F-18 fighter jets, or the Air Force's B-1, B-2 and B-52.

Future researchers could also expand the scope of technology under consideration and focus on software projects or IT-related efforts. Software development projects are increasingly important and expensive. Like military aircraft, software is often delivered late and over budget. Even successfully delivered software is often not well received by users, and software project leaders must wrestle with issues of size and complexity. It would be interesting to examine whether the FIST value set might contribute to better outcomes on software development projects.

The thesis focused exclusively on American projects. Future researchers may want to look at the international community and examine the types of values that guide

development of military aircraft (or other types of systems) in countries like Sweden, France, China or Russia.

This project pointed out that UAV's are inherently FISTy. That is, the typical measures of merit for a UAV are whether or not it is developed quickly, at a low cost, and whether it is both technically and operationally simple. Even the small size of most UAV's is a point of pride. It would be interesting to examine the relationship between a genre's inherent qualities and the design values present in that community. Is the FIST value set really embraced by UAV developers, or is it simply an artifact of the technology's inherent attributes? If such a distinction exists, does it matter? Inversely, aircraft carriers seem to be inherently big, expensive and complex. A future researcher may want to look at the question of what the FIST values would mean in the context of a large naval ship development project.

Finally, the FIST approach is built on the assumption that mature technologies are available for project leaders to draw from as they develop systems. This appears to rule out using the FIST approach on basic research projects and similar scientific endeavors, particularly as Simplicity is defined and understood, but perhaps simplicity might be expressed in other ways in the context of basic research. Future investigators may want to examine this field more closely, to determine whether the FIST values set might be able to contribute to the "operational success" of scientists and engineers working in the earlier phases of project research and development.

Appendix A: FIST Rubric

FIST Rubric				
	High **10 pts**	**Medium** **5 pts**	**Low/No** **0 pts**	**Opposite** **-5 pts**
Fast Is Good	Strong, explicit affirmation of the importance of speed. Formal commitment to maintaining deadline (contractual, etc). Contractual incentives to reward early delivery. Concrete steps taken to actually reduce development timeline. Accepts significant risks in order to maintain schedule.	Modest, occasional affirmation of the importance of speed, with caveats. Modest, informal commitment to maintain or reduce deadline. Contractual incentives to reward on-time delivery. Few steps taken to reduce timeline. Accepts moderate risks in order to maintain schedule	Little to no mention of the importance of speed. No commitment (beyond the ordinary) to maintain deadline. No steps taken to reduce timeline or reward on-time / early delivery.	Ambivalence or antipathy towards speed. Explicit support for "taking as much time as we need" Active attempts to increase timeline. Accepts schedule delays rather than accept risks.
Inexpensive Is Good	Strong, explicit affirmation of the importance of low-cost. Formal commitment to maintain budget (contractual, etc) Contractual incentives to reward cost under-runs. Concrete steps taken to actually reduce development cost. Accepts significant risks in order to reduce costs.	Modest, occasional affirmation of the importance of low-cost, with caveats. Modest, informal commitment to maintain or reduce budget. Few concrete steps taken to reduce cost. Accepts moderate risks in order to maintain costs.	Little to no mention of the importance of low cost. No commitment (beyond the ordinary) to maintain budget. No steps taken to reduce cost.	Ambivalence or antipathy towards low-cost. Explicit support for "spending as much money as we need to" Active attempts to increase budget. Accepts cost increases rather than accept risks.
Simple Is Good	Strong, explicit and frequent affirmation of the importance of simplicity. Deliberate steps taken to actually reduce complexity in many	Modest, occasional affirmation of the importance of simplicity, with caveats. Modest attempts to reduce complexity in	Little to no mention of the importance of simplicity. No mention of steps taken to reduce complexity.	Ambivalence or antipathy towards simplicity. Explicit support for / pride in complexity. Active attempts to

	areas (organization, technology, communication, etc).

Heavy reliance on existing, mature, proven technology (TRL 7+).

System capability less than previous systems.

Frequent emphasis on the importance of and reliance on talent. | some areas.

Primarily relies on mature technologies, with some new developments.

System capability moderately less than previous systems.

Occasional mention of the importance of and reliance on talent. | No mention of technology maturity levels.

No mention of the importance of and reliance on talent.

System capabilities match or moderately exceed previous systems. | increase complexity.

Heavy reliance on new developments and technology breakthroughs

System capabilities significantly exceed previous systems.

Explicit reliance on formal, structured process, control and compliance. |
| **Tiny Is Good** | Strong, explicit affirmation of the importance of small.

Formal commitment to maintain or reduce size.

Concrete steps taken to actually reduce size (of org, process, sys, documentation, etc). | Modest, occasional affirmation of the importance of small, with caveats.

Modest, informal commitment to maintain or reduce size.

Few steps taken to reduce size. | Little to no mention of the importance of small.

No commitment (beyond the ordinary) to maintain size.

No steps taken to reduce size. | Ambivalence or antipathy towards small, lean or streamlined approaches.

Explicit support for / pride in bigness.

Active attempts to increase size. |

Outcome	A	F
	Met or surpassed all or most operational requirements, including maintainability and reliability

Delivered operational capability

Users expressed satisfaction

Delivered within a reasonable margin of original cost and schedule baseline

Program replicated or imitated by subsequent projects | Mission failed to meet or surpass a significant number of requirements

System rejected by users

Program cancelled before delivery

Delivered after adding substantial funding and substantial schedule increase

Operational use is severely restricted to a subset of original operational vision or requirement set. |

Appendix B: Instructions To Co-Investigators

This project explores the relationship between the organizational values held by technology development teams and the operational outcomes of the systems those teams and organizations produce. Specifically, it examines the impact of a set of values called FIST, which stands for Fast, Inexpensive, Simple and Tiny.

Attached to these instructions you will find a brief story about a technology development project and a simple coding scheme in the form of a rubric. A rubric is a scoring tool for making subjective assessments, and I ask that you use the rubric to guide your assessment.

It is important to take a moment to define the term "values." A value is a statement of priorities and preferences. An organization's values typically answer the questions "What is important?" or "What is good?" When an organization expresses the FIST values, they are stating "It is good and important to be fast, inexpensive, simple and tiny."

As you read the attached story, please look for "value clues" which indicate the presence of the FIST values. The following sentence is an example of a value clue related to the Inexpensive value: *To reduce costs, the development team accepted risks that previous teams had been unwilling to endure*. This statement illustrates that cost reduction was more important than risk reduction, specifically as compared with other, similar teams. Please note that value clues will not always be explicit and obvious.

The project need not meet *all* the criteria in a particular category in order to merit a particular rating (some stories may not mention risk, for example), but it should meet enough of the criteria for the rating to be reasonable and supportable.

Along with the organization's values, you will also be asked to assess the outcome of the project. Rather than focus on *programmatic* success (i.e. on-time, on-budget delivery of a system that satisfies the documented requirements), you are asked to assess the *operational* outcome using the criteria in the Outcome portion of the rubric.

Thank you again for your help and insight. Please feel free to let me know if you have any questions.

SYSTEM NAME:
F-Score:
I-Score:
S-Score:
T-Score:
Outcome:

Appendix C: Story Data

A Note About The Data

The following pages contain excerpts from a variety of reports, newspaper and magazine articles, books, letters and interviews. These quotations are value clues, selected for analysis because they provide some insight into whether the project leader's organizational and design values align with the FIST value set.

The excerpts are organized under five headings (Fast, Inexpensive, Simple, Tiny and Outcome), depending on their content. In many cases, a particular quotation contains value clues related to two or more of the FIST elements. In those cases, in order to maintain readability and context, I simply included it once, under whichever heading seemed the most appropriate, rather than post the same quote in multiple locations or divide a single quote into smaller pieces. Therefore, a project's lack of quotations under any given heading does not necessarily reflect an absence of value clues related to that value.

It is also worth noting that a value clue may indicate either the *presence* or the *absence* of one or more of the FIST values. A project may, for example, have a large number of quotations under the Fast heading and a very low F-score, because those quotations indicate a rejection or absence of that particular value.

After collecting and analyzing the excerpts, I assigned scores and grades to each project, using the FIST rubric in Appendix A. Because many statements refer to multiple values, several projects have few or no quotations under the heading Tiny (for example), while still earning a high T-score. This is simply an artifact of the approach to grouping

quotations. This might also indicate the Tiny value was an *implicit* rather than *explicit* value. When this is the case, it is discussed in the analysis section for that project.

Inputs provided by the five co-evaluators are included as they were provided, and were not edited (other than the occasional spelling correction). No attempt was made to standardize the format of these inputs.

Finally, readers should understand that the scores assigned to the projects are necessarily subjective, and were deliberately assigned at a high level of granularity, to avoid the misleading appearance of precision in what was emphatically a subjective analysis. No significance is attributed to the relative scores within each category – a *high* high score and a *lower* high score are treated equally.

The conclusions drawn from this research solely depend on the *category* each system ended up in (High or Low), not on the specific numerical score assigned to the system. What matters was simply which side of the line the system was on, not how far from the boundary line it was. Therefore, the conclusions and heuristics would not be significantly affected if a project's score was changed from 25 to 40 or -20 to 0, and the reader is cautioned to not be distracted by the numerical scores nor to draw conclusions based on a point difference of 10 or 15 points. Similarly, the grades were assigned using a binary pass/fail (A or F) scoring, as discussed previously.

PROJECT NAME: NASA's Mars *Pathfinder*

DATES: 1993 - 1997

STORY SOURCE: McCurdy, 2001; Golombek, 1999; McCurdy, 2005

RUBRIC SCORE: 40

>   *F-Score:*10

>   *I-Score:*10

>   *S-Score:*10

>   *T-Score:*10

OUTCOME: A

SAMPLE STATEMENTS:

FAST

"The Pathfinder team, moreover, was asked to design, build and prepare their spacecraft for launch in just 3 years. The Viking team had taken 6." (McCurdy, 2001:61)

"Within aerospace circles, the cost and schedule goals given to the Pathfinder team were widely thought to be impossible." (McCurdy, 2001:61)

"To leave time for testing, Spear insisted that contractors and subsystem managers deliver their hardware no later than halfway through the development cycle. This was a demanding requirement inasmuch as the development phase had already been cut to just three years." (McCurdy, 2001:130)

INEXPENSIVE

"Proponents of the 'faster, better, cheaper' initiative asked the Pathfinder team to put a lander and a rover on the surface of Mars for one-fourteenth of the inflation-adjusted cost of the 1976 Viking mission." (McCurdy, 2001:61)

"To fly frequently, exploration advocates had to fly cheaply." (McCurdy, 2001:62)

"They called it 'Pathfinder' because the project blazed the trail for a new generation of low-cost spacecraft." (McCurdy, 2001:62)

"To further reduce mission costs, the Pathfinder team accepted risks that Viking team members had been unwilling to endure." (McCurdy, 2001:65)

"The Pathfinder team clearly saved money by reducing capability." (McCurdy, 2001:69)

"The Viking team spent $27.3 million to develop the cameras for their landers, approximately $100 million in inflation-adjusted dollars. The Pathfinder team spent just $7.4 million." (McCurdy, 2001:70)

"[Donna] Shirley promised to build a free-ranging rover and stay within NASA's $25 million cap. To avoid cost overruns, she relied heavily on existing technology." (McCurdy, 2001:73)

"The Mars Pathfinder team also saved money by employing fewer people." (McCurdy, 2001:74)

"Ownership of the cost constraint permeated all the way down to the lowest level of the organization… Team members learned that they could not solve a problem by pulling in more people or spending more money." (McCurdy, 2001:98)

SIMPLE

"Land it directly on the surface of Mars, without orbiting or descent engines…" (McCurdy, 2001:62)

"Team members launched one lander, with one radio…" (McCurdy, 2001:66)

"… the most complicated piece of equipment on the Pathfinder mission was the *Sojourner* rover, which cost only $25 million." (McCurdy, 2001:68)

"Advantages in technology allowed Pathfinder and Sojourner managers to develop scientific instruments without the cost overruns Viking team members incurred." (McCurdy, 2001:68-69)

"By the mid 1990's, CCD detectors were a well-established technology…" (McCurdy, 2001:71)

"The Pathfinder team… [concentrated] project management at a single center: the Jet Propulsion Laboratory." (McCurdy, 2001:75)

"They did not include orbital spacecraft or as many scientific instruments as part of their project. They did not operate the *Pathfinder* spacecraft for a long period of time." (McCurdy, 2001:75)

TINY

"Keeping spacecraft weight low enough to permit launch on a *Delta 2* was a major mission goal." (McCurdy, 2001:64)

"The rover team had to develop a small, semi-intelligent robot, about 2 feet long and a foot high that weighed no more than 22 pounds… It had to operate on the modest amount of power generated by a 1.9 square foot solar panel." (McCurdy, 2001:73)

"The central management team never comprised more than about 30 people… The science advisory teams were kept small." (McCurdy, 2001:75)

"Members of the Pathfinder team employed far fewer people for much less time." (McCurdy, 2001:77)

"The notion that a small team of JPL engineers and scientists could develop a spacecraft in less than three years for under $200 million and land it on the surface of another planet was contrary to the history and culture of that Center. Most people thought it could not be done." (McCurdy, 2005:18)

OUTCOME

"… the Pathfinder team developed their spacecraft in 3 years, about half the time that the Viking team took." (McCurdy, 2001:75)

"… the Pathfinder team completed their project with about one-third of the number of people working about one-half of the time." (McCurdy, 2001:75)

"Compared to the Viking mission, the Pathfinder team saved $3.6 billion in inflation-adjusted currency." (McCurdy, 2001:62)

"… the [landing] system worked perfectly, except for a minor glitch when a lander petal got tangled in the deflated airbag." (McCurdy, 2001:67)

"The lander bounced at least 15 times up to 12 in high without airbag rupture, demonstrating the robustness of this landing system." (Golombek, 1999)

"The cameras on the *Viking* and Mars *Pathfinder* landers had approximately the same resolution, but the *Pathfinder* images were much crisper and they cost substantially less." (McCurdy, 2001:71)

"Existing technology in the 1990's helped the Sojourner team develop the free-ranging rover for $25 million without cost overruns." (McCurdy, 2001:74)

"Many people worried that the Pathfinder experience was a 'one time only' event, an experiment that could not be repeated when scientists and engineers tried to apply low-cost, low-weight technologies to a broad spectrum of spacecraft. In fact, the next mission [*Global Surveyor*] replicated the Pathfinder experience." (McCurdy, 2001:120)

"The mission operated on Mars for 3 months and returned 2.3 Gbits of new data, including over 16,500 lander and 550 rover images, 16 chemical analyses of rocks and soil, and 8.5 million individual temperature, pressure and wind measurements… The mission captured the imagination of the public… A total of about 566 million internet 'hits' were registered during the first month of the mission, with 47 million hits on July 8th alone, making the Pathfinder landing by far the largest internet event in history at the time." (Golombek, 1999)

ANALYSIS

As with all of NASA's Faster, Better, Cheaper initiative, *Pathfinder* explicitly affirmed the Fast and Inexpensive values. The program leaders consistently and deliberately stated that it was important and good for the program to be Fast and

Inexpensive, and program success would be determined in part by whether or not the cost and schedule constraints were followed. There was a similarly strong emphasis on simplicity and smallness, both technical and organizational. The outcome was not only successful, it was successfully replicated on a subsequent mission.

CO-EVALUATOR ANALYSIS

RUBRIC SCORE: 35

> *F-Score:*5
> *I-Score:*10
> *S-Score:*10
> *T-Score:*10

OUTCOME: A

FAST – Medium (5)

The MPF project timeline was dictated at program outset: 3 years from design to launch, compared to 6 years for Viking. This timeline is fast for any type of space mission, let alone one to explore another planet.

No evidence was presented that contractual incentives were made to deliver on time. However, the decision to keep development in-house gave the management team increased control over the delivery timelines and schedule milestones.

INEXPENSIVE – High (10)

Everything about the Pathfinder mission was focused on lowering cost. Even the name "Pathfinder" was symbolic of the first of a new generation of lower cost spacecraft.

A primary program goal for the MPF team was to "put a lander and a rover on the surface of Mars for one-fourteenth of the inflation-adjusted cost of the 1976 Viking mission." The MPF team saved costs in all areas (design, technology, launch, and operations) to complete its mission for $265 million dollars, which is extremely inexpensive for this type of mission. Deliberate design and risk acceptance decisions were made to help achieve this cost goal.

The Inexpensive value drove secondary effects in terms of simplicity and size of the technology and the Pathfinder team. Those effects are detailed below.

SIMPLE – High (10)

The concept for actually landing the Pathfinder on Mars is the paragon of simplicity. Previous Mars and moon landing missions used complex engines to control the descent after several orbits. MPF went to a simple design of an inflatable airbag to protect the lander after a direct insertion into the atmosphere. Even simple geometry was used to ensure the lander would emerge from the airbags right-side up.

Simplicity demanded that the team be willing to take risks that are not common on interplanetary missions. These included only having one lander, one radio, a landing point that was easy to access put potentially dangerous, and the aforementioned the landing system.

Simplicity seemed to be a secondary value on this program. Inexpensive was the primary driver, and simplicity had to be enforced to bring the program in on budget. Simplicity was implemented, but forced a reduction in capability. These capability cutbacks were often to the disappointment of the users (i.e. the science community), who had to sacrifice the number and types of instruments, as well as the duration of the mission. While the Pathfinder development team was able to take advantage of technical learning curves and didn't have to pay the cost of invention by their focus on simplicity, the users weren't getting the latest cutting edge science results. According to the FIST principles, however, reductions in capability along with the use of mature technology are both expected in the pursuit of simplicity,

TINY – High (10)

Pathfinder was a small spacecraft, deliberately made so in order to fit on the most inexpensive launch vehicle possible (Delta II).

The Pathfinder development and operations teams were deliberately kept small, with most of the development work done in-house at JPL. This allowed the team to avoid hiring people to coordinate the dispersed activities and further reduced the size of the management and advisory teams. The intentionally short duration and simple design of the mission allowed the operations team to be kept to a few dozen people. Ultimately, the value of "tiny" kept costs down as well, as labor expenses are a major portion of any technology program's budget.

Outcome - A

The Pathfinder program's embodiment of the FIST principles resulted in a successful mission, according to the requirements and expectations. The team met its budget, timeline, and mission parameters. It took risks that didn't result in adverse outcomes due

to the focus, passion, and sheer capability of the people on the team. While the Pathfinder sacrificed some capabilities in terms of redundancy, scientific innovation and mission duration, these issues were accepted from the outset given the "FIST-iness" of the program. Overall the Pathfinder program was judged by the mission team to be a success at the time of the mission, and is regarded by history as one of the most successful space exploration missions ever.

PROJECT NAME: F-16 Falcon

DATES: 1971 - 1979

STORY SOURCE: Hehs, 1991; USAF F-16 Fact Sheet; Burton, 1993; Air Force Studies Board, 2008

RUBRIC SCORE: 40

> *F-Score:* 10
>
> *I-Score:* 10
>
> *S-Score:* 10
>
> *T-Score:* 10

OUTCOME: A

SAMPLE STATEMENTS:

FAST

1971: Lightweight fighter RFP sent out

December 1976: F-16A first flight

January 1979: First operational F-16A delivered (USAF F-16 Fact Sheet)

"We were ready to fly the lightweight prototype on 1 Feb 1974. We found out Northrop wasn't flying until June or July… One of the reasons the Air Force eventually chose our design was that it was closer to a full-scale development than Northrop." (Hehs, 1991:4)

"The development timeline, therefore, was shorter for the individual blocks and within a management and oversight time frame. This approach reduced the threat of instability, in requirements and cost because the expectations were not only measurable but near term." (AF Studies Board, 2008:32)

INEXPENSIVE

Unit Cost: $14.6m (FY98 dollars) (USAF F-16 Fact Sheet)

"If I plot a curve of cost per pound for succeeding aircraft, the F-16 is right on the curve… However, if I plot a curve of unit flyaway cost, the F-16 falls off that curve. It reversed the upward trend in flyaway cost." (Hehs, 1991)

"*Most importantly, the F-16 was the first and last fighter that cost less than its predecessor.*" (Burton, 1993:20; emphasis in original)

SIMPLE

"We were perceived as being anti-technology. Our slogan was 'make it simple.'" (Hehs, 1991)

"We used the technology available to drive the given end, that is, or was, to keep things as simple and small as we could. Our design was a finesse approach. If we wanted to fly faster, we made the drag lower by reducing size and adjusting the configuration itself. If we wanted greater range, we made the plane more efficient, more compact." (Hehs, 1991)

"Question: What were some of the conventions the fighter mafia challenged? Answer: Range was associated with fuel capacity. High speed was associated with bigger engines. Technology was associated with complexity. Twin engine designs were considered safer. Size and cost were associated with capability." (Hehs, 1991)

"We were well aware that the avionics folks would be putting a bunch of gadgets into the airplane, which would increase weight and decrease performance. We stacked the deck. We made the airplane so dense that there wasn't room for all that stuff." (Hehs, 1991)

"… we had to use a given engine, the F100, which had been developed for the F-15…" (Hehs, 1991)

"Question: What was the riskiest portion of your lightweight fighter design? Answer: The fly-by-wire system. If the fly by wire didn't work, our relaxed static stability wasn't going to work… We had a backup that not too many people know about. We designed the fuselage so that if the fly by wire did not work, we could go back to a statically stable design by moving the wing back." (Hehs, 1991)

"In designing the F-16, advanced aerospace science and proven reliable systems from other aircraft such as the F-15 and F-111 were selected. These were combined to simplify the airplane and reduce its size, purchase price, maintenance costs and weight." (USAF F-16 Fact Sheet)

"…the F-16 does not carry the expensive, relatively unreliable, and nonlethal radar-guided missile that seldom had been effectively used at long range, as its advocates promised, prior to the Gulf War." (Burton, 1993:21)

"The YF-16 was to be powered by a single Pratt & Whitney F100 turbofan, whereas the YF-17 was to be powered by a pair of General Electric YJ101 engines." (Dewitte an Vanhastel, 2008)

"…the F-16 was the product of a highly disciplined design process. The combat tasks were decided firt and were not allowed to vary during the design phase. This produced a superior design that was tailored to those specific tasks." (Burton, 1993:133)

"The F-16 featured many innovations in the application of engineering and management concepts, but fundamentally the advances that this aircraft possesses reflect the shrewd application of available technology." (AF Studies Board, 2008:32)

"Follow-on blocks would improve the combat capability in a predictable and stable engineering and management environment." (AF Studies Board, 2008:32)

TINY

"Another reason, besides weight, favors small size. Smaller aircraft have less drag. The airplane's exceptional maneuverability is a consequence of that lower drag and a higher thrust-to-weight ratio." (Hehs, 1991)

"You can, for example, get a higher thrust-to-weight ratio by increasing the thrust. You can also get a higher thrust-to-weight ratio by leaving the thrust alone and reducing the weight, which is what we did on the lightweight fighter." (Hehs, 1991)

"People think that big is better. It's not. With the lightweight fighter, we wanted to achieve our ends through different means. We increased range by reducing size." (Hehs, 1991)

"Question: What is the advantage of being simple and small? Answer: In general terms, it translates into lower weight, less drag, and therefore higher performance. Also a fundamental indicator of an airplane's cost is its weight." (Hehs, 1991)

"So the engine was fixed. That meant the thrust was fixed. If we wanted a high thrust-to-weight ratio, we had no choice but to reduce weight." (Hehs, 1991)

"The way we got the cost down was by getting the size down. That was another motivation for reducing size." (Hehs, 1991)

"The Statement of Work… reflected the Fighter Mafia's philosophy—short and simple. It was only25 pages long, and contractor proposals were forbidden to be longer than 50 pages, a revolution." (Burton, 1993:19)

OUTCOME

"In an air combat role, the F-16's maneuverability and combat radius (distance it can fly to enter air combat, stay, fight and return) exceed that of all potential threat fighter aircraft." (USAF F-16 Fact Sheet)

"With a full load of internal fuel, the F-16 can withstand up to nine G's… which exceeds the capability of other current fighter aircraft." (USAF F-16 Fact Sheet)

"combat record of 72 victories with 0 losses" (Lockheed-Martin F-16 Product Brochure)

"Both the F-15 and the F-16 are outstanding fighters, but the F-16 is slightly better… [in Israel's 1982 Middle East war]… the little F-16 wound up shooting down more enemy aircraft than its big brother. It also suffered fewer hits from enemy fire and had less combat damage to repair." (Burton, 1993:21)

ANALYSIS

The F-16 development team explicitly and firmly expressed the FIST values.

From the start, they affirmed that it was important and good to build an aircraft that was

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inexpensive, simple and tiny, and to build it quickly. The project leaders made constant design decisions to ensure the aircraft would remain low-cost, small and simple, and worked hard to avoid schedule delays.

While the Inexpensive, Simple and Tiny values were explicitly held by the F-16 team, Fast was an implicit value. There are relatively few specific statements in the F-16 literature about the importance of a short development timeline. However, it was clear the project leaders recognized the importance of minimizing the development timeline and delivering an actual aircraft quickly. They did this informally, without an externally-driven deadline. In fact, the project leaders avoided the pitfall of speeding by "not working against an arbitrary schedule." (Hehs, 1991:4) They simply worked quickly, keeping costs, complexity and size down, and delivered sooner than their competitor.

Along with being developed in half the time and at half the cost of its predecessor (the F-15 Eagle), the F-16 has an impressive operational track record. The Falcon is one of the most successful fighter jets ever developed, and according to the Lockheed Martin F-16 Produce Brochure, "More than 4,350 F-16s have been produced for 24 countries." It is clearly a successful project. However, the development effort was not imitated by subsequent development teams.

Later versions of the F-16 were not developed with the same value set, and additional costs, delays and complexities were added on, blurring the idealistic vision of the Falcon's originators. As Burton describes it, "The establishment eventually ruined the later versions of the F-16 by adding tons of high-tech gadgetry, which increased its weight and cost and significantly degraded its performance." (Burton, 1993:26). None the

less, the initial delivery provided a high-performance, FISTy aircraft which has continued

to perform well around the world, despite being "ruined" in later versions.

CO-EVALUATOR ANALYSIS

RUBRIC SCORE: 35

> *F-Score:* 10
> *I-Score:*10
> *S-Score:*10
> *T-Score:*10

OUTCOME: A

I wanted to be methodical and try to keep as much of my own bias out of it. I basically higlighted any place in the document that related to a F.I.S.T. value. What flushed out, to me, was a natural comparison between the F-15 and F-16. There were obviously many other mentions with relation to other stuff, and it wasn't always clear how I should attribute statements.

So, for the purposes of distillation, I took anything that related to the "Fighter Mafia" or austerity advocates, or (later in the document) any of the gov't officials who were pushing for austerity as being F-16.

PROJECT NAME: NASA Near Earth Asteroid Rendezvous (NEAR)

STORY SOURCE: Laufer, 2000; McCurdy 2005

DATES: 1993 - 1996

RUBRIC SCORE: 40

       F-Score: 10

       I-Score: 10

       S-Score: 10

       T-Score: 10

OUTCOME: A

SAMPLE STATEMENTS:

FAST

"… the NEAR spacecraft would have to be launched during a 1-minute crack in a 2-day window in mid-February 1996. If we missed that narrow window, NASA would have to wait 7 years for another window…" (Laufer 2000:122)

"The tight window turned out to be our best ally, because it created a definite sense of urgency for everyone involved and focused all attention on that goal. (Laufer 2000:122)

"… we had to hurry… Every Monday morning each of our lead engineers would give a 3-minute report on how they were progressing against the simple 12-line schedule I had developed… we would finish in 40 minutes and leave the meeting armed with a list of concrete action items that could be followed and tracked." (Laufer 2000:122)

"Developing a spacecraft typically takes three to four years. Discovery allowed 36 months for development. NEAR was delivered in just 27 months." (Laufer 2000:123)

"[NEAR program manager Thomas] Coughlin had a clear vision of the management philosophy necessary to produce a low-cost, short-schedule spacecraft…" (McCurdy, 2005:19)

"… the NEAR team had given themselves considerably less time." (McCurdy 2005:17)

"Had the NEAR team taken on too much, promising to build and test a spacecraft too rapidly with too little money? Team leaders were confident they had not. They did not believe that they had taken on a task that would prove too fast or too cheap." (McCurdy 2005:18)

"The two-year development schedule was the 'foremost design driver' for the spacecraft and its mechanisms, team members noted. Components had to be designed and manufactured in a remarkably short period of time. Team leaders planned to begin assembling the whole spacecraft just 18 months after funding began." (McCurdy 2006:20)

"Most impressive was the short development time. An analysis of NASA space programs suggested that planetary missions required an average of eight years of preparation; a subsequent review of spacecraft difficulties identified insufficient development time as a primary cause of mission failure. The NEAR spacecraft team produced a simple spacecraft—from funding to launch—in just 27 months." (McCurdy 2005:20)

INEXPENSIVE

"A second great motivator was the chance to prove to NASA that the NEAR team could deliver the program at a much lower cost than expected. NASA's first projections budgeted NEAR at $200 million or more, but we estimated the project at $112. NASA was uneasy with our bid and budgeted NEAR at $150 million; we believed we could do it for less." (Laufer 2000:122)

"… the NEAR team had promised to finish the first phase of the project—construction of the spacecraft—for a paltry $122 million, a considerable commitment to the low-cost philosophy." (McCurdy 2005: 17)

"Based on the funds devoted to the development of the spacecraft, NEAR sat near the bottom of the list." (McCurdy 2005:18)

"The NEAR team spent $79 million designing, constructing and testing its spacecraft, excluding scientific instruments… These were small sums by exploration standards." (McCurdy 2005:20)

SIMPLE

"Had I incorporated even half of these good ideas, the spacecraft would never have been built. Only those changes that could be made with negligible or minimal disruption were even considered." (Laufer 2000:123)

"By pushing specs, cost, and trade-offs, and driving decision making to the lowest level possible, we were able to focus on the big picture as laid out in our simple schedule rather than the engineering problems and surprises that normally plague a fast project." (Laufer 2000:123)

"The NEAR and Pathfinder teams sought to produce spacecraft that were simultaneously cheap and reliable and to produce them rapidly. The NEAR team sought to achieve this goal through simple design, high-tech instrumentation, reduced launch costs, calculated risk-taking, and team-based management techniques." (McCurdy 2005:19)

"To reduce the possibility of interactive flaws, team members needed a relatively simple spacecraft. In pursuit of mechanical simplicity, the NEAR team designed a spacecraft with few moving parts." (McCurdy 2005: 19)

"The simplified design reduced cost, cut time, and helped prevent unexpected integration problems as the launch date approached. It also created a spacecraft that was a bit hard to handle." (McCurdy 2005:20)

TINY

OUTCOME

"NEAR chased the asteroid Eros around the solar system for four years, finally orbiting the 21-mile-long object in February 2000. After circling Eros for one year, the renamed NEAR-Shoemaker spacecraft touched down on the asteroid's surface in February 2001, the first such landing in the history of spaceflight." (McCurdy 2005:2)

"Today, at 3:02:10 EST, NASA's NEAR Shoemaker spacecraft traveled its last mile, cruising to the surface of asteroid Eros at a gentle 4 mph… finally coming to rest after its 2-billion-mile journey… it collected 10 times more data than originally planned and completed all its science goals before attempting its descent to the asteroid… When it touched down, NEAR shoemaker became the first spacecraft ever to land, or even attempt to land on an asteroid. The success was sweetened by the fact that NEAR Shoemaker was not designed as a lander." (NASA Press Release, 12 Feb 2001)

ANALYSIS

This project involved a very explicit adoption of the FIST values. The project leaders consistently affirmed that it was important and good to be Fast, Inexpensive, Simple and Tiny, both in terms of technology and organization.

Engineers gave 3-minute reports and used a simple 12-line schedule. While these relate to Fast and Simple, they also are evidence of an organization that values Tiny. Many so-called "good ideas" were rejected because they would have increased the cost, schedule or complexity of the project, demonstrating that project leaders were unwilling to sacrifice cost, schedule or complexity in order to incorporate "high tech" subsystems and components. Decision-making was pushed to the lowest level, simplifying and miniaturizing the organization. Even ease of performance was sacrificed in the name of simplicity, a remarkably bold decision.

The project was an enormous success, providing an order of magnitude more data than originally expected. It even landed on the asteroid Eros, the first time such a maneuver had ever been attempted, despite the fact that it was not designed to be a lander.

CO-EVALUATOR ANALYSIS

Fast: 10
  Similar previous systems took up to seven years to develop, NEAR was scheduled to be launched just 27 months after funding.
  This schedule is referred to as aggressive several places in the document.
  The deadline was a make or break target, if they missed their launch window, it could complete its mission, and this was made clear to the team.

Inexpensive: 10
  The proposed budget was markedly below similar programs and almost 30% below allowed budget, and they still came in under budget.
  The team was so proud of coming in under budget that they held a ceremony (big check and all) to return the unused portion to NASA.
  Took risks to accomplish this, including using solar cells (cheaper) in an environment that they were traditionally not used because the distance from the sun limits their effectiveness.

Simple: 10
  Traditional probes used many scientific instruments, which drove up complexity. But NEAR committed to only using 2 instruments.
  The team was limited to only on mission scientist to simplify the organizational relationships.
  Team focused on using high TRL and very few moving parts (fixed solar cells). To make this work, the team had to use inventive ideas in the arrangement of the components.

Tiny: 10
  NEAR was limited in size by the specific launcher it was authorized to fly on.
  The result was a vehicle that was almost 50% less mass than previous probes.
  Additionally, the delta v budget was very tight, forcing the vehicle to stay within its size budget or risk going over total weight budget.
  The team was very aware of the size issues, and were worried that the vehicle would be over budget all the way up to the official weighing day shortly before launch.

Outcome: A
  NEAR was the first landing on an asteroid, and was never designed to do so (demonstrates both flexibility of the hardware and the operations team)

Quote from the paper - "though 'faster, cheaper, better' is not in use, new programs contain the core features" and it is implied that the success of NEAR played a role in this cultural shift.

The researchers were very happy with the science from NEAR.

It is interesting to note that several programs tried to replicate the processes used by NEAR. Unfortunately, most cut the budgets and staff too close to the bone and wound up being on the wrong side of FIST (too fast, too inexpensive, too simple, too tiny), leading to an official movement away from "faster, cheaper, better". But, over time, the more balanced approach has seeped into some elements of the culture as reported above.

PROJECT NAME: Skunk Works

STORY SOURCE: Skunk Works, Rich, 1994

DATES:

RUBRIC SCORE: 40

    F-Score: 10

    I-Score: 10

    S-Score: 10

    T-Score: 10

OUTCOME: A

SAMPLE STATEMENTS:

FAST

P-80: "Kelly's guys [built]… the cigar-shaped prototype of theP-80 Shooting Star, in only 143 days—37 days ahead of schedule." (pp 112)

HAVE BLUE: "We built two Have Blue prototypes in record time, only twenty months from the day the contract was awarded until I made the first flight." (pp 57)

F-117: "The first stealth fighter squadron, composed of eighteen airplanes and a few spares, was ready to go to battle only five years after the initial Air Force go-ahead…" (pp 91)

F-117: "We started assembly the same time as McDonnel Douglas started the F-18 fighter. They took ten years to produce their first operational squadron of twenty airplanes. We took only five years. And theirs was a conventional airplane, while ours was entirely revolutionary technology." (pp 80)

U-2: "To put an airplane in the sky in only eight months was a tremendous achievement." (pp 132)

INEXPENSIVE

"Lockheed's management agreed that Kelly could keep his tiny research and development operation running—the first in the aviation industry—as long as it was kept on a shoestring budget… So Kelly and a handful of bright young designers he selected took over some empty space in Building 82… That way the overhead was kept low and the financial risks to the company stayed small." (pp 112 - 113)

HAVE BLUE: "It was built on the cheap all the way…" (pp 58)

F-117: "We built eight a year at a fly-away cost of $43 million each. Stealth did not come cheap, but considering the revolutionary nature of the product and the enormous strategic

advantages it afforded, the F-117A was the most cost effective new weapons system in the inventory." (pp 95)

F-117: "… we achieved phenomenal efficiency… At one point I offered to give the government some of its money back… (pp 95)

F-117: "… they actually developed this automated program in only 120 days and at a cost of only $2.5 million. It was so advanced over any other program that the Air Force bought it for use in all their attack airplanes." (pp 95)

SIMPLE

"There shall be only one object: to get a good airplane built on time… Any cause for delay shall be immediately reported to C.L. Johnson… Everything possible will be done to save time." (pp 116)

"The reason why Kelly could move so quickly building the U-2 was that he could use the same tools from the prototype of the XF-104 fighter… Using that tooling would save many months and a lot of money… Each airplane could cost the American taxpayers $1 million, including all development costs, making it the greatest procurement bargain ever." (pp 131)

TINY

U-2: "We had on hand only four engineers and twenty maintenance, supply, and administration people. Nowadays they'd probably use twenty people just to fuel an airplane." (pp 134)

OUTCOME

U-2: "there never has been a single day since that airplane became operational in 1956 that a U-2 isn't flying somewhere in the world on a surveillance operation for the blue-suiters, NASA or the Drug Enforcement Agency. In fact, on more than one occasion over the years, the U-2 may have saved the world from thermonuclear war." (pp 178)

ANALYSIS

The Lockheed Skunk Works shop is the prototypical FIST organization. Throughout its long history, it has consistently and firmly asserted that it is good and important for its projects to be Fast, Inexpensive, Simple and Tiny. Projects which do not meet those criteria are rejected. It shows that it is possible for an organization to consistently implement the FIST values and produce effective systems.

Skunkworks reliably delivered simple, low-cost, high-tech aircraft on short timelines, to support the DoD and CIA's highest priority missions. These systems went on to be used effectively across a wide spectrum of operations. The Skunk Works approach is widely imitated, from Raytheon's *Bike Shop* to the Office of Naval Research's *Swamp Works* to countless other lesser-known "skunk works" units in organizations across various industries.

PROJECT NAME: PAVE LOW III

DATES: 1975 - 1980

STORY SOURCE: Gambone, 1988;

RUBRIC SCORE: 40

> *F-Score:*10
>
> *I-Score:*10
>
> *S-Score:*10
>
> *T-Score:*10

OUTCOME: A

SAMPLE STATEMENTS:

FAST

"The schedule, being so short and rigid, required self-motivated personnel with high morale and personal initiative." (Gambone, 1988:23)

INEXPENSIVE

"He [Terry] also thought it could be done for $3 million." (Gambone, 1988:24)

"… the ROC [Required Operational Capability] emphatically indicated that cost would be a determining factor in acceptance of any future effort on this ROC." (Gambone, 1988:40)

"Since the APQ 141 was only a flight test radar and the APQ 148 was only a TA radar, the development costs and program risks associated with these radars were high. Thus, these systems were eliminated." (Gambone, 1988:40)

"Since all systems had approximately the same performance, the cost and interface problems were the deciding factors. CMC agreed to loan PAVE LOW a Doppler nav system free of cost. In addition the CMC 208V required no interface hardware, thus it was chosen." (Gambone, 1988:41)

SIMPLE

"Some people believed that the Gunship team was the most talented group within ASD to accomplish the tasks required." (Gambone, 1988:23)

"He [Terry] discussed the situation with Colonel Bell, director of the ASD SPO for PL II, and suggested that the program could be done in-house utilizing the Gunship personnel." (Gambone, 1988:24)

"Since the computer interfaces with many of the avionics systems a tried and proven computer was needed. The prime candidate was the IBM CP993 computer. This computer was picked for the following reasons: a.) Prototype hardware was available at WPAFB for no additional costs to the Air Force. b.) The Program Office had extensive experience with this computer… d.) The IBM computer was in the Air Force inventory." (Gambone, 1988:42)

TINY

"Colonel Terry had a staff of one civilian, one military officer, and a secretary. There was a test organization of approximately four people who were in charge of flight testing. There was also a large procurement section and a large engineering section. There were no 'managers.'" (Gambone, 1988:21)

"The preliminary planning… was accomplished over several months using a small selected group of personnel." (Gambone, 1988:24)

"In addition to cost, other factors such as performance, size, weight, risk, reliability and inventory status were used for selecting equipment." (Gambone, 1988:40)

"… since the FLIR would be mounted on the nose of the a/c it was also necessary that it be compact in size and weight." (Gambone, 1988:40)

"For picking a TF/TA radar the most significant factors were risk, or development cost, and the size." (Gambone, 1988:40)

"The LN15S was picked since it h ad less weight, cost, size, and better performance." (Gambone, 1988:41)

OUTCOME

"In 1990, Pave Lows from the 20th Special Operations Squadron led the way for Army AH-64 Apaches during an air strike, thus opening the air war in Operation Desert Storm." (Air Force MH-53J Fact Sheet)

"MH-53J's were used in a variety of missions during Desert Storm. Pave Lows were among the first aircraft into Iraq when they led Army AH-64 Apaches to destroy Iraqi early warning radars and opened a hole in enemy air defenses for the opening air armada. In addition to infiltration, exfiltration and resupply of special forces teams throughout Iraq and Kuwait, Pave Lows provided search and rescue coverage for coalition air forces in Iraq, Saudi Arabia, Kuwait, Turkey and the Persian Gulf. An MH-53J made the first successful combat recovery of a downed pilot in Desert Storm. Following the war, MH-53J's were deployed to Northern Iraq to support Operation Provide Comfort, assisting displaced Kurds. Pave Lows were also used extensively during Operation Just Cause in Panama." (GlobalSecurity.org MH-53J Pave Low III page, 2006)

ANALYSIS

Gambone's story of the Pave Low III's history is full of value clues, explicitly stating the reasons for various judgments and decisions made on the project. These value clues inevitably point to the FIST value set at work within the Pave Low III project.

When faced with a short, rigid schedule, the Gunship SPO responded by applying talented, motivated people, rather than complaining about inadequate time or resources (as happened in the FIA project). This shows a strong appreciation for the importance of rapid development and delivery, i.e. the Fast value. When faced with the opportunity to use immature components that would have required extensive and expensive testing (and thus had a high risk of failure and delay), project leaders decided to simply eliminate the sub-system rather than incur additional cost and schedule risk. This willingness to sacrifice performance and functions rather than increase the system's cost, schedule and complexity is clear evidence of the FIST values at work. Project leaders deemed it better to keep the cost and complexity down than to add an expensive subsystem or function.

The Pave Low III program is one of the most explicit examples of the Tiny value being applied to both the organization and the technology. Gambone's story frequently refers to the team's preference for small components and small work teams. Rather than rely on formal processes and structures, the Gunship SPO explicitly relied on a small group of talented, hand-picked personnel as the means of ensuring a positive outcome. This not only indicates a strong commitment to the Tiny value, but also a deep understanding of the importance of being Simple and the relationship between these two values. Recall from the FIST Rubric, reliance on people is an indication of Simplicity,

while reliance on formal structures and processes tends to indicate a preference for complexity.

The Pave Low III has an impressive operational record, following the example of earlier versions of the Pave Low family. It was one of the first aircraft to enter Iraqi airspace in the first Gulf War, and provided a wide range of support to special forces teams. It is clearly an operational success.

PROJECT NAME: P-51 Mustang

DATES: 1939 - 1942

STORY SOURCE: Nelson, 1944; Carson, 1985; Sanders, 1942; Anon, 1975; Bjarnoe, 2006

RUBRIC SCORE:

F-Score: 10

I-Score: 5

S-Score: 10

T-Score: 10

OUTCOME: A

SAMPLE STATEMENTS:

FAST

"The original *Mustang*, designed and built for the British in less than 120 days…" (Nelson, 1944:127)

"[North American] had probably been working on drawings of what was to become the P-51 as early as the previous summer, well before the official go-ahead. Consequently, when historians point out that the prototype was completed in only 117 days, they conveniently overlook the fact that actual work had begun at least three and possibly four months prior to the May 1 official start date." (Carson, 1985:33)

"… they already had a clear idea of what they wanted and… they used the data from Curtis… to cut trial and error time and to find tune their own concept of what a modern fighter should be." (Carson, 1985:33)

"… North American promised to deliver 320 of the new aircraft before September 1941, only 17 months after the signing of the agreement…" (Carson, 1985:33)

"It must have been obvious to the British, that development of the NA-71 [the P-51's original designation] was well along when they signed their initial contract on May 1, 1940…" (Carson, 1985:33)

"… when developing the P-51 a kind of modularization and parallelization of the sub-processes was applied. The airframe was for example divided into sections which could be developed independently as the interfaces were defined from the beginning which is the same principle used in contemporary modular product-architectures. This made it possible to execute parallel product development and set-based design, which means that several designs of the same module were developed concurrently and consequently the decision about the final design could be postponed. The result of this made it possible to work with new, advanced designs in a very limited time frame." (Bjarnoe, 2006:44)

INEXPENSIVE

SIMPLE

"The record of North American's P-51 *Mustang* fighter proves, however, that it is both possible and practical to create a single basic design that can be modified, as military needs dictate, to keep abreast of requirements." (Nelson, 1944:127)

"These achievements are, from an engineering standpoint, remarkable—because they were accomplished by a plane that does not to any extent embody previously unknown engineering features, but rather employed refinements of known accepted practices." (Nelson, 1944:129)

"It is an extremely simple airplane and has such perfect handling qualities as to put a smile of joy on the face of any fighter pilot." (Sanders, 1942)

"The problem of supply of a new airplane is not as great as it first seems due to the fact that engines, guns, radios, instruments, and man [sic] other parts are the same as those used on P-40s." (Sanders, 1942).

TINY

"The P-51 is requested in preference to the P-47 because of its smaller size, ease of maintenance, economy of operation, range and because many of the accessories for it are already available in this area [Karachi Air Base, India]." (Sanders, 1942)

OUTCOME

"… the *Mustang* has been credited as the best low-altitude cooperational craft, the most versatile dive bomber, the fastest high-altitude fighter, and the plane with the greatest range." (Nelson, 1944:127)

"… it possessed the longest range of any single engine fighter in the war." (Nelson, 1944:129)

"The Mustang has literally been used for every type of task during its thirty-five years of service… A total of 14,819 Mustangs were manufactured by North American; in the European Theater of Operations the Mustang accounted for nearly 5,000 enemy aircraft destroyed in aerial combat and over 4,000 aircraft destroyed on the ground; and the Mustang flew over 213,800 combat sorties while in USAAF service. That is a record that is unlikely to be beaten by any other manned fighter." (Quarterly Review, 1975)

ANALYSIS

The P-51 Mustang is one of the most famous and successful fighter

aircraft of the WWII era, both operationally and programmatically. It was an engineering,

logistical and operational success, and sets an example we would do well to follow even today. The P-51 was designed and built in 117 days, which was the first of several records it would eventually break. Nearly 15,000 Mustangs were manufactured over the years, and countless books have been written praising the Mustang's contributions to national defense.

The principles that guided its development shine light on several important aspects of the FIST value set, specifically the use of mature technologies. Nelson made a point of bragging that the Mustang "does not to any extent embody previously unknown engineering features, but rather employed refinements of known accepted practices." (Nelson, 1944:129). This emphasis on "known accepted practices" and studious avoidance of "unknown engineering features" is a key indicator of the Simple value.

Pilots made a similar point of bragging about how simple the aircraft was to fly and maintain. By relying on readily available systems and components, North American was able to minimize the cost, timeline, complexity and maintenance difficulties associated with the new aircraft. As Col Sanders explained in his letter from Karachi Air Base, the P-51 could be maintained easily with existing supplies and tools, which was a significant measure of merit, particularly in such an austere AOR. The Mustang's outstanding performance, of course, was equally important, but a high-performance aircraft that cannot be supported and supplied in a remote region like Karachi would have been worse than useless.

In terms of the Inexpensive value, the Mustang is consistently described in terms of its "economy of operation," and praised for being "economical to produce." Given the

natural trend in military technology toward increasing costs, this economy is most certainly not accidental and is at least indirect evidence of the Inexpensive value. As a measure of merit, however, the Mustang's economy is an implicit value rather than an explicit. It is something project leaders and fliers bragged about, but not as strongly as they bragged about the Mustang's operational effectiveness. Recall that what project leaders brag about is usually an indicator of what they value, and so the Mustang gets a relatively high I-score.

PROJECT NAME: F-5 Freedom Fighter / Tiger

DATES: 1954 - 1959

STORY SOURCE: Gentry, 1976; AF Museum Fact Sheet; Burton, 1993; FAS.org; Martin & Schmidt, 1987;

RUBRIC SCORE: 35

> *F-Score:* 5
>
> *I-Score:* 10
>
> *S-Score:* 10
>
> *T-Score:* 10

OUTCOME: A

SAMPLE STATEMENTS:

FAST

"The F-5 first flew on July 30th, 1959, and deliveries to the Tactical Air Command for instructing foreign pilots began in April, 1964." (National Museum of the Air Force Fact Sheet)

INEXPENSIVE

Cost: $756,000 (USAF Museum F-5 Fact Sheet)

"The F-5 is a small, low-cost fighter version of the T-38 trainer… Thousands of F-5's have been sold to Third World countries because they are relatively inexpensive." (Burton, 1993:99)

"The F-5 can be operated at one third of what it costs to operate an F/A-18." (FAS.org)

"The F-5 is a supersonic fighter combining low cost, ease of maintenance and great versatility." (National Museum of the Air Force Fact Sheet)

"This transition to the F-5 adversary aircraft will provide Active and Reserve Navy pilots with air-to-air combat training at significant savings to the taxpayer." (FAS.org)

SIMPLE

"The Department of Defense (DoD) objective was to develop a simple, inexpensive but reasonably capable fighter which could be provided or sold to those countries which could not afford, or lacked the capability to operate, more complex aircraft." (Gentry, 1976:5)

TINY

Wingspan: 25 feet 10 inches (USAF Museum F-5 Factsheet) [The F-16's wingspan is 32 ft 8 inches, per USAF F-16 Factsheet]

Weight: 8085 pounds empty (USAF Museum F-5 Factsheet) [F-16 weighs 19,700 without fuel, per USAF F-16 Factsheet]

"In 1962, the Air Force had awarded Northrop a contract to produce the F-5 Freedom fighter, a very lightweight (13,000-pound), twin-engined tactical fighter…" (Gentry, 1976:5)

OUTCOME

"Approximately 1100 were delivered to 15 countries over an eight-year period." (Gentry, 1976:5)

"The F-5 is a supersonic fighter combining low cost, ease of maintenance and great versatility. More than 2,000 F-5 aircraft have been procured by the USAF for use by allied nations." (USAF Museum F-5 Fact Sheet)

"Northrop's F-5 program produced a highly lucrative international fighter and a relatively successful aircraft by most measures. Thirty-two countries have purchased more than 2600 F-5's with 28 different configurations of the F-5E alone." (Martin & Schmidt, 1987:12)

"The F-5… is suitable for various types of ground-support and aerial intercept missions, including those which would have to be conducted from sod fields in combat areas." (USAF Museum F-5 Factsheet).

ANALYSIS

The F-5 is one of the few modern aircraft designed explicitly around the FIST values. Northrop focused on developing a small fighter that would be inexpensive and simple, in terms of both ownership and operations, so the Inexpensive and Simple values are the most explicit. This combination of simplicity and low cost was the plane's main attraction for prospective buyers. It was easily transformed into several variants, further evidence of the flexibility inherent in simple designs.

The Fast value was less explicitly held, at least as expressed in the stories, interviews and case studies reviewed in this project. However, Fast was clearly an

implicit value, as evidenced by the program's development timeline and sense of urgency. Further, the emphasis on keeping costs low seems to necessitate a short development timeline, since excessive delays would increase the cost of the system.

The F-5's operational success is impressive. It is widely used in other countries as a primary jet fighter, and as an aggressor aircraft by the US military (Air Force and Navy). The US uses a trainer version of the F-5, the T-38 Talon, to train Air Force and NATO pilots, as well as NASA astronauts. NASA also uses it as a chase plane to support shuttle missions.

PROJECT NAME: A-10 Thunderbolt II

DATES: 1967 - 1975

STORY SOURCE: Burton, 1993; USAF A-10 Fact Sheet; Doscher, 2008; Jacques & Strouble, 2008; Dahl, 2003.

RUBRIC SCORE: 35

> *F-Score:* 10
>
> *I-Score:* 10
>
> *S-Score:* 10
>
> *T-Score:* 5

OUTCOME: A

SAMPLE STATEMENTS:

FAST

"The first production A-10A was delivered to Davis-Monthan Air Force Base, Ariz., in October 1975." (USAF A-10 Fact Sheet)

"The RAD [Requirements Action Directive] for the A-X … cited an urgent need (IOC of 1970) which dictated maximum employment of existing state-of-the-art technology in its design, thus allowing for a compressed conceptual design phase." (Jacques & Strouble, 2008:17-18)

"The required IOC of December 1970 was considered high risk with respect to cost and schedule, but achievable if the concept definition phase was reduced to a four month contract definition followed by competitive source selection…" (Jacques & Strouble, 2008:21)

"The change to a competitive prototyping approach had a significant effect on IOC, with the new projected IOC now in FY76." (Jacques & Strouble, 2008:30)

"Contractors would have 3 months to respond to the RFP and the government intended to complete its evaluation of proposals and make award within a 75 day period." (Jacques & Strouble, 2008:32)

"The Air Force also believed the A-10 to be closer to production, thus allowing for faster progress…" (Jacques & Strouble, 2008:39)

INEXPENSIVE

"These shells [fired by an A-10] are very effective at destroying tanks, trucks, bunkers, and most targets of interest on a battlefield. They cost only $13 apiece, a far cry from $100,000 for a maverick missile." (Burton, 1993:25)

"The cheapest airplane to buy and operate, it was also the most effective ground support airplane in the world." (Burton, 1993:26)

"The specifications also demanded that the aircraft cost less than $3 million." (Coram, 2002:236)

"Usually there are no cost constraints on an aircraft-design program… In all the history of the Air Force, the A-X was the single exception. It *had* to be cheap. It *had* to cost less than the Cheyenne." (Coram, 2002:234)

"In a force cost analysis, the A-X had the lowest total force cost due to the small force required, which could be traced to high availability over the battlefield, high sortie rates and high sortie effectiveness." (Jacques & Strouble, 2008:27)

"In order to reduce these costs, the Air Force was to provide guidance stressing simplicity of design, ease of maintenance, and the importance of keeping costs of the A-X to a minimum… In order to achieve cost savings, the specified performance requirements were not to be considered firm specifications but goals…" (Jacques & Strouble, 2008:33)

SIMPLE

"The nose of the plane [A-10] is pointed at the target and a burst of cannon shells squeezed off—simply, quickly and efficiently." (Burton, 1993:25)

"The A-X was to use an existing state-of-the-art engine in order to achieve an early IOC [Initial Operating Capability]… The A-X would also use existing state-of-the-art equipment for avionics." (Jacques & Strouble, 2008:18)

"The avionics for the A-X were specified in terms of a 'skeleton' package (below minimum requirements), a 'lean' package (met only minimum requirements), and three add-on packages that would supplement the 'lean' package." (Jacques & Strouble, 2008:20)

"… it was intended that simplicity of design would lead to a shorter development time, lower life cycle cost, reduced maintenance times, increased sortie rates and the ability to operate from austere bases." (Jacques & Strouble, 2008:22)

"In October 1969, Secretary of the Air Force Harold Seamans chose an alternative that was termed 'Parallel Undocumented Development.' This approach would require a minimal amount of documentation during the competitive prototyping phase to encourage innovation and initiative on the part of the contractors." (Jacques & Strouble, 2008:30)

TINY

"Dr. John Foster [DDR&E] stated that 'the proposed aircraft seems to be too large… A smaller, less-costly, quick reaction aircraft seems more appropriate.'" (Jacques & Strouble, 2008:29)

"The representative A-X from DCP-23A [Development Concept Paper] was slightly smaller, lighter and cheaper than that of DCP-23." (Jacques & Strouble, 2008:30)

"In keeping with the philosophy of minimum documentation for the Parallel Undocumented Development phase, the SPO [System Program Office] was to be manned on an austere basis." (Jacques & Strouble, 2008:32)

"The A-X request for proposal (RFP), including all attachments and 'boiler plate' was 104 pages, and it limited each contractor's response to 585 pages. This represented a sizeable reduction in the RFP for its time…" (Jacques & Strouble, 2008:32)

OUTCOME

"The A-10s turned out to be one of the true success stories of the [first Gulf] war. They represented only 15 percent of the combat aircraft in the war, yet, according to the *Air Force Times*, 'flew about a third of the total sorties and were responsible for more than half the confirmed bomb damage' against the enemy. Put another way, the A-10 was responsible for more damage to the enemy than all the other combat aircraft put together…" (Burton, 1993:242)

"During approximately 8,624 combat sorties, only six A-10s were lost. Two of them crashed while landing, which resulted in one of the two pilot fatalities that occurred." (Burton 1993: 242)

"The A-10C is already saving lives. The upgraded Warthog has flown nearly 1,000 combat sorties since it came online in August, providing combat air support to U.S. and NATO forces in Afghanistan." (Doscher, 2008)

ANALYSIS

The development of the A-10 Thunderbolt II (aka the Warthog) was strongly guided by the FIST value set, both out of necessity and by the designer's philosophical preferences. It is no secret that the Air Force historically has not placed a high priority on the Close Air Support (CAS) mission area, and during "the 1950's and early 1960's, the USAF made no effort to field an aircraft specifically designed for CAS" (Dahl, 2003:2), preferring instead the more glamorous missions of air superiority and long-range strike. Thus, project leaders strove to keep a low profile for the A-10 (particularly at the project's start), by delivering quickly and at a low cost.

Few systems demonstrated the unified nature of the FIST values as strongly as the A-10. Descriptions of the project leaders' priorities and values consistently use phrases

like "simplicity of design would lead to a shorter development time, lower life cycle cost…" and "in order to reduce costs, the Air Force stressed simplicity of design…" This sometimes makes it difficult to isolate which of the four FIST components was the driving factor, perhaps because no single aspect of FIST had priority. The A-X project leaders valued the *entire* FIST set, as an indivisible priority, not as a set of attributes to be selected piecemeal in trade-off analyses.

The A-10 specifications required a low cost system, which drove the designers to use existing, mature systems and technologies, which lead to a shortened development schedule. The project leaders were staunch advocates of simplicity, both in the system's design and operation as well as organizationally. They explicitly preferred the low-cost, simple munitions fired by the A-10's gun over the expensive high-tech alternatives.

The A-10 is one of the most operationally successful aircraft in the USAF inventory, and stories of its resilience are legendary. As Burton pointed out, although the A-10 only represented 15% of the combat aircraft in theater during the first Gulf War, it was "responsible for more damage to the enemy than all the other combat aircraft put together…" (Burton, 1993:242). It doesn't get much better than that.

PROJECT NAME: F-20 Tigershark

DATES: - 1986

STORY SOURCE: Jurkus, 1990; Martin & Schmidt, 1987;

RUBRIC SCORE: 35

> *F-Score:* 5
>
> *I-Score:* 10
>
> *S-Score:* 10
>
> *T-Score:* 10

OUTCOME: Failure – zero sales.

SAMPLE STATEMENTS:

FAST

"The rollout of the first F-20 Tigershark occurred 32 months after the program go-ahead—it came out a month ahead of schedule." (Martin & Schmidt, 1987:5)

"Northrop rapidly tested the Tigershark through its flight envelope in order to enable foreign air force pilots to fly the aircraft as soon as possible for marketing reasons." (Martin & Schmidt, 1987:6)

INEXPENSIVE

"The strategy of Northrop with respect to the F-20 was to design, produce and develop an intermediate export fighter in accordance with United States FX [Foreign Export] policy for an export market estimated to be in the thousands… It was designed to be less expensive to buy, own and operate." (Jurkus, 1990:61)

"The cost of ownership and the expense of owning and operating the F-20 was less than half the cost of an F-16, according to Northrop." (Jurkus, 1990:62)

"It is evident that from early on in the program, Northrop was concerned over the cost-effective producibility of the Tigershark. They took great steps towards ensuring that they would be able to produce a quality product that could be sold for a reasonable price." (Martin & Schmidt, 1987:9)

"The proposed fixed price for the F-20s was $15 million with support (1985 dollars), substantially less than GD's going price of $18 million for the F-16C." (Martin & Schmidt, 1987:17)

SIMPLE

"Northrop's export fighter program has been characterized by a consistent philosophy. In designing and developing an aircraft, performance must not outweigh cost, reliability, maintainability, and operability… Their typical client country hasn't had the kind of

support structure to operate and maintain a 'Ferrari' level aircraft, but has done well with a 'Ford Escort' aircraft" (Martin & Schmidt, 1987:3)

"A corollary to the Northrop philosophy stated above is a willingness to give up a little extra performance in order to make significant gains in terms of affordability, reliability, maintainability, and operability. Northrop had never pushed the edge of the technical 'envelope' with the F-5 program. They did not intend for the Tigershark to be an exception. Northrop put these principles into practice by selecting F-20 subsystems which were either proven, or which had good paper 'specs' with respect to reliability." (Martin & Schmidt, 1987:4)

"The F-20 also met its 'operability' goal: foreign pilots were able to fly the single seat F-20 after just two days of simulator training." (Martin & Schmidt, 1987:6)

TINY

OUTCOME

"After five years, one billion dollars in development costs, and strong lobbying and marketing efforts, Northrop Corporation's F-20 Tigershark was recently laid to rest with little fanfare." (Jurkus, 1990:59)

"To the trained eyes of prospective buyers its performance was dismal." (Jurkus, 1990:62)

"Northrop and many observers claimed that, from a technical point of view, the program was a resounding success. In point of fact, no one can know. No F-20's were ever sold." (Martin & Schmidt, 1987:1)

"Northrop considers the F-20 program to have been a great R&D success. They are correct in the sense that theF-20 met or exceeded Northrop criteria for performance, reliability, maintainability and operability." (Martin & Schmidt, 1987:3)

"The F-20 accomplished approximately 1500 flights before the program was terminated… On the basis of its 1500 flights, the F-20 Tigershark seemed to score rather well. It had a much faster scramble time than the F-16… The F-20 was inferior to the F-16 in operating range (10-15 percent less range depending on altitude, speed, etc.) and in the amount of armaments that could be carried." (Martin & Schmidt, 1987:6)

"The MFHBF [Mean Flight Hours Between Failures] for the F-20 was 4.2 at the time of program termination. The F-16 had accumulated a 3.2 MFHBF over many years of operational use. The F-20 required maintenance manhours per flight hour (MMH/FH0 of 15.1 during its test run. The F-16 had accumulated a MMH/FH of 33.9." (Martin & Schmidt, 1987:6)

ANALYSIS

Following their success with the F-5, Northrop explicitly focused on building a FISTy aircraft. This is seen by their reliability on proven technology and multiple decisions to sacrifice performance in order to make gains in affordability, reliability, maintainability and operability. The literature did not make many explicit statements in support of the Fast value, but given the importance of simplicity and cost, along with the potentially large foreign market, Fast seems to be an implicit value.

The Reagan administration's change to the previous Carter administration's position on foreign weapon sales forced the F-20 to compete against the fully-configured F-16, instead of against the degraded version approved for foreign sale under Carter. As soon as foreign buyers had the option to purchase the F-16, the F-20's appeal was much diminished.

It is interesting to note that the F-16 was originally the epitome of the FIST model, but when later versions of the F-16 are put alongside the new F-20, the Falcon ends up looking expensive, complex, etc. This is not just a question of comparative attributes between the F-16 and the F-20, but rather it indicates a change in the F-16's design philosophy. As Burton's analysis of later versions of the Falcon explains, "This beautiful little aircraft [the F-16], which had been the best dogfighter in the world, was now just another overpriced, overweight, underperforming monument to high technology." (Burton, 1993:103-104). So, a system's FIST score is not only relative, it is also not static.

Martin & Schmidt point out, "Now that F-16A's had been sold to Venezuela and Pakistan, most developing countries began requesting similar aircraft, regardless of their

budgets or realistic assessments of their security threats." (Martin & Schmidt, 1987:14-15). Rather than base their purchase decision on an assessment of the actual threat environments they faced, foreign governments preferred the larger, more expensive, more complex F-16, and they "demanded the highest level of technology they could acquire." (Martin & Schmidt, 1987:21).

This was a psychological and emotional decision on the part of foreign governments, based on a desire to appear fully modern and tough. It should be pointed out that much the same decision process goes on in the US as well, so they were only following the DoD's example. In the end, the very values which led to the development of the Tigershark as a simple, reliable, low-cost fighter jet actually undercut its marketability, because these values were not shared by the potential customers.

The F-20 program was a resounding failure—Northrop was not able to sell even a single F-20. The Tigershark's limited performance was certainly a contributing factor, as was the change in US policy on weapon exports. However, the primary reason appears to be the striking mismatch between Northrop's design values and the values of its potential clients.

CO-EVALUATOR ANALYSIS
RUBRIC SCORE: 30
  F-Score: 0
  I-Score: 10
  S-Score: 10
  T-Score: 10
FAST: I didn't detect any value or "stated preference and priorities" with regard to being fast. Although the case study reported the program accomplished its first rollout a month

ahead of schedule, that is an outcome and not necessarily a product of having a "fast" value. For example, being fast could actually be a product of trying to be simple. Therefore I gave it a score of 0.

Inexpensive: You couldn't read this case study without coming away knowing that developing an inexpensive product was a HUGE driving factor. From the beginning when CEO Tom Jones released his basic philosophy, affordability was included while the other measures (reliability and maintainability) were products of wanting to have affordable life-cycle costs. Additionally they made specific design decisions to remain affordable. Therefore I gave it a score of 10.

Simple: Northrop made choices for the purpose of decreasing complexity. A great example of this was the choice of engine that would have half the parts of the F-16 engine. Also, they aimed to use proven technologies. Although I think they valued simplicity, it wasn't simplicity for simplicity sake. It was simplicity for reliability and maintainability sake. However, to determine if they value something highly I don't believe the purpose of why they value it is necessarily important, what is important is they did value it and made decisions based on it; I gave this a score of 10.

Tiny: I was on the fence with this one. I didn't see any explicit comments about being tiny or small. For this one I had to look at behavior and infer what they valued based on it. While there weren't "Strong, explicit affirmation of the importance of small" I believe there was "concrete steps taken to actually reduce size". These include the redesigning of the production center to decrease the size and bureaucracy of production, also there was comments about the small size of documentation. The case study made it clear there was less documentation than what would have accompanied a government sponsored program and the initial CEO design philosophy was kept to just one page. I didn't believe these were "modest and informal commitments" so I therefore gave it a score of 10.

Outcome: Without a doubt the outcome of this program falls squarely in the "Mission Failure" category. The system was rejected by users and the program cancelled before delivery. Score F

Additional Comments: At first after reading the case study I thought I would have to score this program twice. Once for pre-Reagan arms sales policy and once for post-Reagan arms sales policy. This is because program behavior changed dramatically after it was decided they were competing against the F-16. However, I ultimately decided that even though their actions changed their values didn't. I got the impression they still wanted to stay as inexpensive, simple, and tiny as possible while adding some more capability to compete better. Therefore, I determined it was fair to grade this only once.

Your warning on the "instruction to Co-investigators" page to not focus on programmatic success but to focus on operational outcome was very important for this particular case study. By all indications this was a program that produced a good airplane on schedule and budget while being affordable. But that just wasn't enough. While Northrop valued

FIST, the world didn't. The world didn't want to evaluate their threat environment and determine the best airplane to meet that threat while weighing performance vs. cost. They wanted the best, period. They wanted what the U.S. was flying whether that was in their interest or not. I think of those program managers, engineers and others at Northrop who did so much right but still failed and it reminds me how uncertain anything is in this business.

PROJECT NAME: A-1 / AD Skyraider

Note on names: the BT2D-1 became the AD-1, which was eventually christened the Skyraider. Crews referred to the AD as the "Able Dog."

DATES: 1944 - 1957

STORY SOURCE: USAF Museum Fact Sheet: Douglas A-1E Skyraider; Johnson, 2008; Boyne, 2007

RUBRIC SCORE: 30

> *F-Score:*10
>
> *I-Score:* 5
>
> *S-Score:*10
>
> *T-Score:*5

OUTCOME: A

SAMPLE STATEMENTS:

FAST

"The Navy men liked everything about the idea except the extra 30 days; They informed Heinemann they wanted to see a presentation of his new design proposal at 9 the next morning! In truth, Heinemann wasn't wholly unprepared. He and his top staff members, Leo Devlin and Gene Root, had for several weeks been sketching out ideas for a totally new design." (Johnson, 2008:2)

"The presentation was over by late morning, and the three men were told to keep their seats and wait. By noon they got an answer: Douglas was authorized to cancel the BTD program and fund construction of 25 preproduction examples of the proposed model, the XBT2D-1. BuAer [Navy Bureau of Aeronautics] gave them exactly nine months to get the plane in the air. When Heinemann returned to the El Segundo plant, his instructions to his staff and employees were terse: 'Nothing must interfere with the completion of this aircraft on schedule.'" (Johnson, 2008:2)

"On March 19, 1945 – almost nine months to the day from Heinemann's meeting in Washington – the first XBT2D-1 lifted off the runway at El Segundo. Such was the rush that the plane had flown with landing gear struts and wheels borrowed from a Vought Corsair and an older version of the R-3350 engine…" (Johnson, 2008:2)

"Heinemann and his El Segundo staff moved at a breakneck pace to address each fault identified by NATC." (Johnson, 2008:3)

"… a little over 19 months after its first flight, BuAer declared the AD-1 ready to join the fleet. Heinemann had not only caught up with Martin, he was miles ahead." (Johnson, 2008:3)

INEXPENSIVE

SIMPLE

"Though using the same Wright R-3350 power plant, it was a far simpler design…" (Johnson, 2008:2)

"… the XBT2D-1 was less complex overall, and thus cheaper to build and easier to maintain [than competing aircraft from Martin, Curtiss and Kaiser]."

"According to his logbook, he [Capt William Smith, USMC) received 4.3 hours' checkout and familiarization time, after which he immediately began flying combat sorties in interdiction of enemy supply lines and close air support of UN troops." (Johnson, 2008:1)

"The Skyraider made its first flight in March 1945, and for the next 12 years Douglas continually improved it through several versions." (USAF Museum Fact Sheet)

"… could it be routinely and safely operated from carriers by 'nugget' aviators (i.e. inexperienced ensign and junior grade pilots on their first cruise)? The new AD's passed this test with flying colors, as every squadron, each with its share of nuggets, completed carrier qualifications without serious incident." (Johnson, 2008:3)

TINY

OUTCOME

"The airplane quickly became popular with pilots and maintenance crews, and they soon took to calling it the 'Able Dog.' … By comparison, the introduction of Martin AM-1's to squadron service in 1948 was marked by frequent accidents and excessive maintenance, and by late 1949 the remaining examples of the 151 Maulers built were replaced by new Ads."

"Because of its ability to carry large bomb loads, absorb heavy ground fire and fly for long periods at low altitude, the A-1E was particularly suited for close-support missions." (USAF Museum Fact Sheet)

"… after that first week there was no question in my mind that our AD's were the best planes in the world for the job expected of us… Even after all these years of progress, I believe the AD is still the best airplane ever made for close-in attack option… better, in fact, than anything flying today." [former U.S. Marine Corps Captain William C Smith, who flew with Marine Attack Squadron 121 in the Korean War] (Johnson, 2008:1)

"Overall performance and handling characteristics were rated as 'exceeding expectations.'" (Johnson, 2008:3)

"When NATC [Naval Air Test Center] resumed evaluations of newly modified AD-1's in the fall of 1946, test pilot reports were highly enthusiastic. …the plane was graded as the best dive-bombing platform NATC had ever tested. Equally important, NATC regarded

the AD-1 as above average in terms of maintainability and logistical support required."
(Johnson, 2008:3)

"Ads were the only planes capable of delivering 2,000-pound bombs with dive-bomber precision against hard targets like mountain bridges and hydroelectric dams." (Johnson, 2008:4)

"A-1's were judged the best planes in Southeast Asia for escorting troop-laden helicopters." (Johnson, 2008:5)

"Though never intended for air-to-air confrontations, two A-1H's… share in the shoot-down of a North Vietnamese MIG-17 on June 20, 1965. Then on October 9, 1966, Lt. j.g. W. Thomas Patton of VA-176, flying an A-1H from USS Intrepid, sent another MiG-17 down in flames near Hanoi." (Johnson, 2008:5)

ANALYSIS

The Douglas A-1 Skyraider development story offers a significant amount of evidence that the project leaders held to the FIST values. To begin with, the design and development was accomplished at a breakneck pace. In fact, according to some reports, the Skyraider was designed in a single night at the Sattler Hotel in Washington DC. (Boyne, 2007:88). The truth is the design work actually began "several weeks" before that fateful night, but whether measured in weeks or hours, the design was completed in record time. In fact, this part of the story highlights one of the "tricks" to finishing early – start early.

While the Navy only gave the Douglass team a single night to produce the design, the designers were able to draw from existing designs already under development, which they had begun in anticipation of the need. The end result was an ability to deliver a combat aircraft design proposal in less than 24 hours… and to deliver the first prototypes in less than nine months.

In order to produce the design and the prototypes in such short order, the small project team necessarily pursued a design philosophy that valued simplicity. This

preference for speed and simplicity is clearly in evidence when we read that Douglass spent the next twelve years updating and improving the aircraft. That is, they deemed it more important to deliver a first-generation aircraft on time than to deliver a fully-capable, "perfect" aircraft. They did not allow their design modifications and tweaking to interfere with the need to deliver actual hardware, and thus they maintained a strict focus on being Fast and Simple.

The team's emphasis on simplicity was also in evidence by the fact that pilots with minimal training could fly the Skyraider with confidence. Even more telling is the fact that the aircraft was popular with maintenance crews.

The remaining two FIST values – Inexpensive and Tiny – are less in evidence. This is partly due to the relative dearth of data on the Skyraider, which was developed over 60 years ago. But while the few sources did not spend much time explicitly discussing Inexpensive and Tiny, there are some clues that the project leaders did indeed hold to these values. However, these values were apparently implicit, not explicit, and thus the Skyraider's I-score and T-score are lower.

The Skyraider's operational record is as impressive as they come. Beloved by pilots and maintainers alike, it has a long record of distinguished service in WWII, Korea and Vietnam – even including the shoot-down of a couple MiG-17 jet fighters (an impressive accomplishment for a propeller-driven bomber). It is clearly a successful aircraft.

PROJECT NAME: XP-75 / P-75 Eagle

DATES: 1942-1945

STORY SOURCE: Holley, 1987; Thornton, 1946;

RUBRIC SCORE:25

> *F-Score:* 10
>
> *I-Score:* 10
>
> *S-Score:* 5
>
> *T-Score:* 0

OUTCOME: F – project cancelled

SAMPLE STATEMENTS:

FAST

"… the object of this development was to provide, with a minimum of delay, a fighter type airplane having exceptional climb performance. Engineering and production was to be expedited…" (Thornton, 1946:1)

"Engineering work proceeded as rapidly as possible throughout the winter of 1942-1943 and spring and early summer of 1943." (Thornton, 1946:2)

"In September 1941, the corporation [General Motors] approached Maj Gen O.P. Echols, the commanding general of Materiel Command, with a proposal to develop a fighter aircraft in a remarkably short time by using, as far as possible, structures, controls, and accessories already in full production for other aircraft in order to obviate the need for long delays in tooling up for production." (Holley, 1987:587)

"Only the main fuselage itself would have to be developed anew. By such short-cuts, the plane was expected to be ready for flight testing in six months." (Holley, 1987:587)

"… the air force [*sic*] took steps to shorten the delays—first, by increasing the number of experimental models to be procured from two to eight to be sure there would be a sufficient number to carry out exhaustive flight tests, and second, by issuing a letter of intent to contract for a mass-production order for 2,500 P-75's." (Holley, 1987:588)

"Engineering and construction proceeded at an accelerated rate following these increased orders." (Thornton, 1946:2)

"Deliveries were expected to begin by May 1944, approximately nine months hence, a phenomenally short time for such a complex undertaking." (Holley, 1987:588)

"When air force [*sic*] officers estimated that it would take at least six months to eliminate these problems, pushing the projected date for reaching peak production past the middle of 1945, it was clear that the time had come to kill the whole project." (Holley, 1987:591)

"One can only speculate that it was the urgent necessity of getting a superior fighter into production as rapidly as possible that led to the experiment." (Holley, 1987:592)

"… the tremendous pressure for immediate production which did not allow sufficient time for carefully planned development. In spite of these conditions, the difficulties were largely corrected and a generally satisfactory design had evolved by the time the first production airplanes were ready." (Thornton, 1946:2)

INEXPENSIVE

"… the Materiel Command signed a cost-plus-fixed-fee contract for two experimental fighters, XP-75, at the relatively modest estimated cost of $428,271, for delivery in six months." (Holley, 1987:587)

"After considerable negotiation the air force [*sic*] agreed to $4,450,702 as the estimated cost of the eight experimental airplanes, but allowed GM a fixed fee of no more than $75,163 or 2.65 percent of the original estimated total, a figure well below the usual 4 or 5 percent fee." (Holley, 1987:589)

SIMPLE

"Engineering and production was to be expedited by using certain major assemblies such as wing panels, empennage, and landing gear from existing production airplanes in a new design around the most powerful liquid cooled engine available." (Thornton, 1946:1)

"By enlarging the tail surface, most of the apparent instability could be overcome, but this meant it would no longer be possible to use the ready-built, off-the-shelf stock design already in production…" (Holley, 1987:590)

"To make matters worse, the Allison engine, which had been rushed into production before it was thoroughly debugged, was not performing up to expectations…" (Holley, 1987:590)

"The remedy, eventually devised, was to extend the ailerons out to the wingtips to insure greater stability and control. But this, too, required reworking the standard ready-built wings…" (Holley, 1987:590)

"… more and more evidence emerged to indict the whole scheme to use off-the-shelf stock components to build a superior high-performance aircraft." (Holley, 1987:591)

TINY

"Each such modification added weight…" (Holley, 1987:590)

"Echol's espousal of the XP-75 is all the more curious in view of the massive size of the plane. With its 49-foot wingspan, it was substantially heavier than virtually any other successful World War II fighter." (Holley, 1987:592)

OUTCOME

"Every new model aircraft has bugs which have to be ironed out; this was to be expected. But the faults encountered in the XP-75 were more than minor. The test pilot reported that the plane lacked stability and displayed a distressing tendency to stall and spin when making tight turns, the maneuver most essential to fighter aircraft." (Holley, 1987:589)

"On October 4, 1944, the chief of air staff, Lt. Gen. B.M. Giles, signed the order terminating the contract." (Holley, 1987:591)

ANALYSIS

The XP-75 / P-75 Eagle project failed to deliver the promised performance, and so the project was cancelled shortly before World War II ended. It thus earns a grade of F, for failing to provide a successful operational capability.

The XP-75 development team clearly valued speed. In fact, rapid development was a cornerstone of the project. Along with an aggressively short schedule, the XP-75 had an austere budget and a strong preference for using existing, mature technology (which indicates the Simple value). The project leaders thus appear to have embraced many of the FIST values. However, there are a few indications that the FIST approach was not entirely adopted in this project, and even when the FIST values were present, they were often misapplied or misunderstood. Conflicting values also emerged as the experiment progressed, limiting the team's ability to fully express the FIST values. When World War II ended, the need for the P-75 was gone and so the project was cancelled.

The emphasis on speed led to cutting some corners in the development planning stage (i.e. "speeding"). This introduced additional difficulties in the effort, which were fortunately corrected in relatively short order. So, while the project leaders may be guilty of speeding, they managed to constrain the impact of that error.

The real shortcoming was in the area of complexity and simplicity. Project leaders severely underestimated the complexity involved with integrating pieces of existing airframes into a new airframe. Each of those pieces had been optimized for the original aircraft, and most had to be modified before they could be used on the P-75. The designers seemed to have aimed for simplicity but instead achieved simplisticness.

Ford failed to appreciate the dynamic nature of the threat environment, which drives essential design modifications to fighter aircraft. Holley points out "Changes in design are dictated not by the whim of meddling government bureaucrats, as Ford suggested, but rather by advances in the performance of enemy aircraft that must be countered." (Holley, 1987:582) Thornton similarly observes "The changing tactical situation soon resulted in modification of the development…" (Thornton, 1946:1). While the FIST approach tends to minimize requirements instability, it does not do away with instability altogether, and despite its aggressive development schedule, the P-75 was exposed to more design changes than many longer programs. This high rate of instability and necessary change limited the team's ability to keep things simple.

Further complicating matters, performance was a top priority. Holley explains "…General Arnold, in his capacity as commanding general of the Army Air Forces, made it clear that everything depended on the performance of the initial experimental aircraft. 'If it does not meet our requirements,' he wrote, 'all orders may be cancelled; everyone must understand this.'" (Holley, 1987:589) Expecting the initial experimental aircraft to perform well and meet all the requirements raises the importance of performance ahead of timeline or budget, thus diminishing the role of the FIST values. In

fact, the FIST approach by necessity has a strong tolerance for risk and failure, and tends to work best when following an "imperfectionist" mindset, with the understanding that rapid development allows for time to try again. A perfectionist expectation that the initial aircraft flawlessly meet all the requirements is not compatible with the FIST approach.

Clearly, the initial experiment was not a complete success. Holley writes "…in the latter half of 1942, the air force was desperate to get a superior fighter… the XP-75 was a long shot… When the experimental plane failed to achieve its promised performance, the gamble failed." (Holley, 1987:593). It is unknown whether subsequent attempts would have led to better outcomes. By cancelling the project after a single attempt, the Air Force reduced its opportunity to learn from the failure and apply those lessons in subsequent trials.

This story also shows that even a FIST project can be overcome by events. The end of World War II removed much of the impetus behind the P-75 development, despite the speed with which it was developed. The project was started too close to the end of the war, and once the fighting stopped, there was little apparent need for an experimental pursuit aircraft. The threat environment had changed, and with it, the national defense priorities. So, while FIST projects tend to minimize the risk of delivering capabilities after they are no longer needed, it does not guarantee this outcome.

PROJECT NAME: Mine Resistant Ambush Protected (MRAP) Vehicles

DATES: 2007 - 2008

STORY SOURCE: Jones, 2007; Sullivan, 2008;

RUBRIC SCORE: 15

> *F-Score:* 10
>
> *I-Score:* 0
>
> *S-Score:* 5
>
> *T-Score:* 0

OUTCOME: A

SAMPLE STATEMENTS:

FAST

"In late January, MSCS [Marine Corps Systems Command] challenged industry by awarding nine separate Indefinite Delivery, Indefinite Quantity (IDIQ) contracts for 36 initial MRAP test vehicles. The IDIQ contracts required these initial vehicles to be produced within 60 days. However, in less than three weeks, five of the vendors demonstrated their reliability to produce vehicles meeting Marine Corps survivability requirements, production numbers and delivery timelines." (Jones, 2007)

" 'We want the maximum number of survivable vehicles, with proven performance, in the shortest time to deliver,'" said Paul Mann, MCSC's program manager for MRAP… '…we hope everyone's product is as good as they state so we can expedite production orders. Theater Commanders have an urgent and compelling need for these vehicles. It is up to all of us to act fast.'" (Jones, 2007)

"… said Barry Dillon, MSCS's executive director. 'The vehicles… need to be fielded as soon as possible… We are encouraging [industry] to produce vehicles faster. The faster we can field quality, safe MRAP vehicles, the more lives we can save.'" (Jones, 2007)

"DOD designated the MRAP program as DOD's highest priority acquisition, which helped contractors and other industry partners to more rapidly respond to the urgent need…" (Sullivan, 2008:2)

"The Secretary [of Defense] also approved a special designation for MRAP—a DX rating—that requires related contracts to be accepted and performed on a priority basis over other contracts without this rating." (Sullivan, 2008:9)

INEXPENSIVE

"To date, more than $22 billion has been appropriated to acquire more than 15,000 MRAP vehicles…" (Sullivan, 2008:1).

"Although DOD's MRAP acquisition approach has provided a rapid solution to battlefield threats, the approach has also created a number of challenges in acquiring and

sustaining mine resistant vehicles—challenges that will likely have short- and long-term impacts on capability and budgets." (Sullivan, 2008:10)

SIMPLE

"DOD used a tailored acquisition approach to rapidly acquire and field MRAP vehicles. The program established minimal operational requirements and relied heavily on commercially available products." (Sullivan, 2008:2)

TINY

OUTCOME

"We ran over an IED and the round sounded like nothing more than an M-80. Nobody was injured except our truck got a few holes in the tool boxes and two tires went flat—but it was out on another mission the same day." (Jones, 2007)

"The highly concurrent test and production strategy for the MRAP vehicle helped to quickly identify the vehicles that met requirements for crew protection but resulted in the fielding of vehicles with significant operational issues as well as the acquisition of a small quantity of vehicles that won't be fielded." (Sullivan, 2008:10)

ANALYSIS

The MRAP team clearly emphasized Fast above all, even going so far as to have the SECDEF create a special acquisition category to ensure the MRAP moved forward as fast as possible. As of 15 Jul 2008, "about 6,600 of the vehicles have been fielded," (Sullivan, 2008:1) which is an impressive feat. It is not entirely clear, however, that the MRAP team avoided some of the "speeding" pitfalls, such as increased costs and schedule delays. As Sullivan points out, "DOD's plan for logistical support beyond the first 2 years is still being developed." (Sullivan 2008:11). This might be evidence of an avoidable strategic cost caused by tactical, short-term thinking.

MRAP leaders emphasized speed and sacrificed cost, potentially driving up costs to a greater degree than necessary. One wonders what would have happened if the team

had implemented the Inexpensive value, alongside the Fast value, and insisted on being both Fast and Inexpensive. However, some of the decisions made in the interest of speed have the potential to help keep costs down. For example, using 9 different IDIQ contracts could foster competition between vendors, which is precisely the kind of thing a project leader would do to express the Inexpensive value. Unfortunately, the vendors are not working from a common blueprint and each type of MRAP is different from the others, making maintenance and operations slightly more complicated.

To date, the operational outcome seems positive. Marines and soldiers who use the vehicles seem genuinely satisfied and reports indicate many lives have been saved. However, it is still too early to say definitively whether the MRAP will be a success over the long run.

PROJECT NAME: E-3 Sentry (AWACS)

DATES: 1965 - 1977

STORY SOURCE: Grier, 2002; Cowdery & Skillman, 1995; GAO report, 1973; Ulsamer, 1974;

RUBRIC SCORE: 25

       *F-Score:*10

       *I-Score:*5

       *S-Score:*10

       *T-Score:*0

OUTCOME: A

SAMPLE STATEMENTS:

FAST

On Dec 22, 1965… the AWACS effort was officially born… in March 1977, the first AWACS was formally delivered to Tactical Air Command…" (Grier, 2002:2,3)

"The Brassboard radars were designed, fabricated, tested and installed in the flight test aircraft at Boeing in less than two years… This was rather incredible considering the complexity of the radar and instrumentation." (Cowdery & Skillman, 1995:5)

"Because of the 'crash' nature of the program, most of the system debugging occurred at Boeing." (Cowdery & Skillman, 1995:5)

"A crash effort resulted in a redesigned master oscillator that provided adequate stability and was installed soon after flights began." (Cowdery & Skillman, 1995:6)

"On November 7, 1972, Boeing successfully completed the Airborne Tracking Demonstration, 4 months ahead of schedule." (GAO, 1973:1)

"In the view of AWACS System Program Director Brig. Gen. Lawrence A. Skantze, a major delay in the program might be tantamount to its termination." (Ulsamer, 1974:70)

"The significant schedule dates in the September 1972 SAR remained unchanged except for the "Rollout Of The First DDT&E Aircraft" milestone which improved by 4 months -- from May 1975 to January 1975. This improvement resulted from use and reconfiguration of one of the two Brassboard aircraft -- the Hughes radar equipped aircraft – instead of waiting to develop and equip a third aircraft." (GAO, 1973:5)

"Brig. Gen. Lawrence A. Skantze, AWACS System Program Director, stresses that the E-3A development and acquisition effort 'has been tailored to proceed at a deliberate pace, leaving time for review at distinct phases of the program…" (Ulsamer, 1974:71)

"According to General Skantze, the AWACS test program focused on two key objectives from the very beginning: To identify the most difficult task and to ensure that it is being tested early and, secondly, to provide a structured test program that will provide, at each

milestone, solid evidence of the performance status of the system and its subelements." (Ulsamer, 1974:76).

"Because of the success of the radar test program, it became possible to speed up the AWACS test and evaluation schedule across the board." (Ulsamer, 1974:76).

INEXPENSIVE

"… in January 1973, the approved program was based on a 4 engine rather than an 8 engine configuration; had a program cost of $2,467 million, for a total reduction of $194 million…" (GAO, 1973: 2)

"As of January 19, 1973, the approved program cost estimate was reduced to $2,467 million. The Air Force is to make more cost reduction … program, a cost goal of $2,284 million having been established." (GAO, 1973:3 – copy damaged and partially unreadable).

"Budgetary constraints at the time of AWACS's first DSARC in July 1970 caused the Air Force to 'trade down' to a basic AWACS system…" (Ulsamer, 1974:76).

"… some reduction in time-on-station was more than made up for by the lower cost of using TF33 engines already in the Air Force's inventory in surplus quantities." (Ulsamer, 1974:76).

SIMPLE

"… the Pentagon treated development of the system as a high-priority effort. For example, AWACS had its own streamlined procurement rules…" (Grier, 2002:2)

"'The total complexity of this system… far exceeds things I've worked on before,' said Ed Froesse, Boeing's vice president for the AWACS program." (Grier, 2002:5)

"To deal with the many problems that arose during the flight tests, both contractors shipped many of the engineers to Boeing so they would be available for trouble-shooting around-the-clock." (Cowdery & Skillman, 1995:5)

"There is no compelling reason for lengthy airframe and engine testing because the AWACS aircraft is a modified Boeing 707-320… AWACS engines are those of the Air Force's C-141, similarly proved in many years of service." (Ulsamer, 1974:70)

TINY

OUTCOME

"Twenty-five years ago, on March 24, 1977, Boeing delivered the first basic production version of the E-3 Sentry to Air Force officials at Tinker AFB, Okla. The ensuing quarter century has shown the AWACS to be indispensible, often the first system to go into action when a threat arises and the last to leave once operations cease." (Grier, 2002:1)

ANALYSIS

The E-3 Sentry (AWACS) development effort is an excellent example of the importance of context when assessing a project. The Air Force spent a lot of money during the 11 years it spent developing the AWACS, and the aircraft's avionics was often described as highly complex. At first glance, this seems to be the opposite of the FIST values. However, the unique nature of the aircraft leaves analysts with few (if any) appropriate systems for comparison. Upon closer inspection, there are many indications that the FIST values guided and shaped the decisions made by AWACS project leaders.

More than 11 years passed between the start of the AWACS effort and delivery of the first operational aircraft. However, within that timeframe, project leaders seemed to place great value on speed, even stating that a significant delay would be cause for termination. BGen Skantze was essentially saying that it was *important and good* to deliver on time, and slow delivery might as well be no delivery, thus providing evidence of the Fast value. The developers made a point of focusing on the difficult projects early, rigorously tested components, and cleverly avoided the temptation to cut corners in the name of speed. Recall that a system's F-score is not based on how long it takes to deliver, but on whether speed is *valued*.

Early critics complained the AWACS cost too much and would not perform well. The critics were clearly wrong about the performance, but their assessment of the cost is worth considering. Project leaders were willing to slightly reduce performance (time-on-station) in order to save money by using existing engines. Had they valued performance more than cost, they would have pushed to spend more money on new engine designs. In

1973 (four years before the first delivery) the GAO reported some cost reductions, but those reductions correlated with a decrease in the number of airframes, from 5 down to 3 DT&E aircraft. (GAO, 1973:2). This is not necessarily a direct sign of the Inexpensive value, but in the overall context, it seems to indicate the value's presence.

The AWACS is physically very complex, with an impressive number of interconnected components, functions, sub-systems and missions. With a flight crew of four and a mission crew of 13-19, it also has one of the largest crew size of any military aircraft, contributing further to its complexity. However, project leaders simplified as often as they could. Specifically, they used an existing airframe and existing engines, incorporating mature technology whenever possible. Even the procurement rules were streamlined.

The E-3 Sentry is a widely recognized for making significant contributions to national defense, and has a long, proud history of operational success, thus earning an operational grade of A.

CO-EVALUATOR ANALYSIS
F: High (10) (several instances of wanting to move program quickly but still smartly)
I: High (10) (some discussion on reducing budget and cutting back number of engines and total number of aircraft as well as organizing to provide for future block upgrades down the road)
S: Med (5) (little on the fence between H/M since built on previous and avail tech but did require pretty good amount of additional R&D and test so went med)
T: Low)0) (didn't really see much in this area except mentions of expanding to include NATO/allies)
Outcome: A

PROJECT NAME: NASA's *Viking*

DATES: 1970 - 1980

STORY SOURCE: McCurdy, 2001

RUBRIC SCORE: -10

> *F-Score:* 0
>
> *I-Score:* -5
>
> *S-Score:* -5
>
> *T-Score:* 0

OUTCOME: A

SAMPLE STATEMENTS:

FAST

"The Pathfinder team, moreover, was asked to design, build, and prepare their spacecraft for launch in just 3 years. The Viking team had taken 6." (61)

INEXPENSIVE

"Viking was a classic NASA mission: complex, redundant and expensive." (61)

"The final cost of the Viking biology instrument, however, was much higher. Due to cost overruns, the biology instrument actually cost $220 million (inflation-adjusted) dollars—5 times the original estimate." (68)

"When the project began, Viking managers estimated that the imaging system could be designed and built for $6.2 million. The actual cost ($27.3 million) was 4 times that amount." (70)

"NASA officials originally estimated that they could develop the biology package for $11.3 million. The actual cost was $59.5 million." (72)

"[the *Viking's* computer's] cost grew from $3.4 to $28.1 million." (74)

"The Viking team spent $51 million on initial operations in the period immediately following the first landing. In inflation-adjusted dollars, that is $174 million more than spent by the Pathfinder team."

SIMPLE

"Viking team members designed an elaborate landing system, with computers, parachutes, radar altimeters, and a throttleable rocket engine. They developed a redundant radio communication system…" (65)

"The *Viking* landers had more capability than the *Pathfinder* spacecraft." (68)

"Scientists recommended that project engineers incorporate a simpler design with less capability… The technically sophisticated design was retained." (71)

"The biology package weighed 33 pounds and contained 40,000 parts." (72)

"The only way to pack four experiments into a small, lightweight container was to make the package complex. In an instrument this complex, any single-point failure threatened the whole system." (72)

TINY

"The Viking mission, by contrast [with *Pathfinder*] required a larger launch vehicle." (64)

"The Viking cameras were bulky affairs… Each lander had two." (70)

"The people developing the biology package were under tremendous pressure to simultaneously reduce cost, weight, and complexity." (72)

"The computer on the *Viking* lander weighed 52 pounds… The *Viking* lander required 17 times as much electric power as the *Pathfinder* lander." (74)

"The Viking project, at the height of its activity, employed 538 people at the Langley Research Center, 1,650 people at the Martin Marietta Aerospace Center, an unknown number of people at the Jet Propulsion Laboratory, and 69 scientists on 13 advisory teams." (75)

OUTCOME

"Between 1962 and 1996, the United States and the Soviet Union sent 19 robotic missions to Mars. Only six successfully completed their objectives… Mars, it would seem, eats spacecraft… The Viking program bought two spacecraft that landed on the Martian soil and two spacecraft that studied the planet from orbits around Mars." (61)

"Although the resulting images were spectacular, Viking program managers paid for this decision with substantial cost overruns." (71)

ANALYSIS

There is no evidence the *Viking* project team held to the FIST values. The program was consistently described as complex, redundant and expensive in several sources quoted above, by advocates as well as critics. Performance and reliability were clearly more important to project leaders than speed, simplicity or low-cost technologies. It was not considered a negative that the project cost so much, took so long or was so

large and expensive. In fact, when simpler designs were proposed, they were rejected in favor of more complex solutions. The Viking team was committed to taking as much time as necessary to ensure optimal performance and minimize risks on this very difficult mission.

The program was clearly successful, as *Viking* operated for years in one of the most difficult environments NASA has ever attempted. However, it is worth mentioning that the effort was not replicated and the US did not attempt a second Mars landing until *Pathfinder*, 20 years later.

PROJECT NAME: C-5A Galaxy

DATES: 1957 - 1973

STORY SOURCE: Gregory, 1989; AF Center for Systems Engineering C-5A Case Study, 2005;

RUBRIC SCORE: -15

> *F-Score:* 0
>
> *I-Score:* -5
>
> *S-Score:* -5
>
> *T-Score:* -5

OUTCOME: A

SAMPLE STATEMENTS:

FAST

"It resulted in the publication of the MATS Qualitative Operational Requirements (QOR) in October 1961 [1] and the System Operational Requirements (SOR) 214 for Heavy Lift Logistics Weapon System on 25 March 1964, and the release of the RFP in December 1965. Note that the whole process took seven years, starting with the early vision, to build the program consensus, develop the budget plan, and define the requirements." (CSE Case Study, 2005:16)

"The first flight of the C-5A occurred on 28 June 1968, 33 months after contract award" (CSE Case Study, 2005:14)

"Operational effectiveness/mission analysis studies covered range, payload, speed, and airport conditions, both at takeoff and landing. The entire cargo/transport aircraft community, the contractors, the development planners, the users, and the technologists were deeply involved in the assessment process. It resulted in the publication of the MATS Qualitative Operational Requirements (QOR) in October 1961 [1] and the System Operational Requirements (SOR) 214 for Heavy Lift Logistics Weapon System on 25 March 1964, and the release of the RFP in December 1965. Note that the whole process took seven years, starting with the early vision, to build the program consensus, develop the budget plan, and define the requirements." (CSE Case Study, 2005:16)

"The C-5A Program was characterized by an excellent pre-Milestone A and Milestone A-to-Milestone B process." (AF Studies Board, 2008:37)

"The time available to redesign the wing was inadequate to conduct a systems engineering assessment of the new design… The net effect of all this activity during source selection was to excessively constrain costs, schedule and performance to such tight and rigorous limits that there was no hope of being able to perform to the requirements of the contract." (AF Studies Board, 2008:37)

"The Air Force spent over $2 billion more than the original budget, and it took 10 years longer to finish the production with fewer aircraft than originally planned." (AF Studies Board, 2008:38)

INEXPENSIVE

"As for the C-5A, it was a watershed. Its cost overrun crossed the billion-dollar line, thus engineering the transition of public perception of the military-buying system and the defense industry from a team that could invent anything, that could turn technology into first-rate hardware unequalled anywhere, to an apparatus that was wasteful, dishonest and incapable of producing anything that worked or stayed within cost targets." (Gregory, 1989:107-108)

"C-5A program was plagued by cost overruns from the very beginning. The cost overrun was not unexpected by either the Air Force or the contractor. The Air Force had predicted a most probable cost of $1.86 billion as opposed to the contractor's best and final estimate of $1.71 billion on 4 September 1965. The actual cost of the original contract grew by another $64 million by December 1965. No one estimated costs as high as the eventual program overrun to $3.5 billion for the development effort plus the 115 aircraft in Run A and Run B." (CSE Case Study, 2005:22)

"The enormous cost overrun had multiple causes. Key reasons included: (1) the original cost estimate was aggressively low, influenced by the contractor's expectation of an ancillary benefit in the form of follow-on for commercial air vehicle design; (2) the perceived low cost estimates of the competitors…"(CSE Case Study, 2005:22)

SIMPLE

"… the C-5 was to have an unusual drive-through main cabin, with vast cargo doors at both front and rear. In fact, the whole nose section of the airplane swung up and over the cockpit. And the landing gear could kneel, adjusting on the ground for differing loading-ramp heights. On top of that complexity, the C-5A looked like a winged centipede on the ground because of short but heavy struts supporting a couple of dozen balloon tires to allow it to land on grass fields." (Gregory, 1989:109)

TINY

"But building a big airplane like the C-5A was not just a matter of scaling up the smaller C-141. When the increase in size passed a certain point, technical challenges and changes cropped up." (Gregory, 1989:110)

"When the C-5 aircraft first entered the inventory in 1970, it was the largest aircraft in the world, and it is still the largest transport cargo aircraft in our inventory. It was the first of the behemoths." (CSE Case Study, 2005:v)

OUTCOME

"The success of the C-5 transport aircraft is underscored by the performance of the fleet as an operational system and its heavy lift support in all of our conflicts from Vietnam to Iraq. It still accomplishes tasks that no other military aircraft, such as the new C-17 or any derivative of commercial cargo aircraft, can perform, and has consistently carried more cargo than any other aircraft in the time of war." (CSE Case Study, 2005:vi)

"The C-5A fleet has demonstrated success in operation, but, as will be discussed, the development of the aircraft was plagued by a major technical failure in the design of the structure, most notably the wing and pylon." (CSE Case Study, 2005:5-6)

ANALYSIS

The C-5A Galaxy is the largest aircraft in the US inventory, with a successful operational track record that extends over four decades. It provides unique capabilities to the military and is clearly an operational success. While some statements from the C-5A stories may initially seem to be value clues in support of the FIST values, closer examination reveals this to not be the case. The development effort cost $2B more than originally envisioned, and it was delivered 10 years behind schedule.

These unfortunate programmatic outcomes were largely driven by the complexity and size of the aircraft, and the project leaders' emphasis on delivering a new system using unproven capabilities and technologies. This preference for complexity and immature technologies lead to extensive delays and increased costs.

While technical problems had a negative impact on cost containment, the cost problems can largely be traced to the fact that neither the government nor the contractors believed (or intended to achieve) the initial cost estimates. That is, there was an informal mutual agreement that the aircraft would not keep to the aggressive budget, despite the

implementation of a new methodology called Total Package Procurement Concept (TPPC).

Secretary of Defense McNamara described TPPC as a way to "scientifically manage a major weapon system" (CSE Case Study, 2005:22), but it ended up contributing to, rather than preventing, cost and schedule over runs. This pattern is consistent with many acquisition reform efforts, which inevitably end up exacerbating the problems they are designed to solve (Ward, 2009).

It worked like this: with the government's full knowledge and tacit approval, the contractor deliberately underbid, based partly on a perception that its competitors were also submitting low bids. Rather than viewing cost and schedule constraints as positive and valuable, they expected to make up the difference on the subsequent contract phases, in which they hoped to secure additional funds and time. Indeed, they eventually got an extra $2B and 10 years. These overruns were higher than expected, but the fact that they happened in the first place was a surprise to no one.

This situation highlights the difference between project leaders who actually understand and value the FIST values and those who are merely paying lip service to the idea of being fast, inexpensive, simple and tiny. The TPPC-induced constraints were viewed as barriers to be overcome, not as goals to achieve. Speed, low-cost and simplicity were not measures of merit, nor were they considered desirable attributes. The end result was that the USAF spent $2B more than expected and waited an extra decade for delivery of the capability.

PROJECT NAME: Crusader Artillery

DATES: 1995 - 2002

STORY SOURCES: Tracy, 2004; Loeb, 2002; Emerson, 2002; Erwin, 2003; Veith, 2002; Rumsfeld, 2002; Charette, 2008.

RUBRIC SCORE: -15

> *F-Score: -5*
>
> *I-Score: - 5*
>
> *S-Score: 0*
>
> *T-Score: -5*

OUTCOME: F – Program Cancelled

SAMPLE STATEMENTS:

FAST

"…in development since 1994… The army wanted to buy 480 crusaders, the first of which would go into service in 2008." (Loeb, 2008).

"Crusader is fully funded, on schedule and within budget; it will start fielding to the Counterattack Corps in 2008." (Emerson, 2002) [NOTE: Crusader was cancelled two months after Emerson's article was published]

INEXPENSIVE

"Defense Secretary Donald H. Rumsfeld announced yesterday he intends to cancel the Army's $11 billion Crusader artillery program so that money could be invested in more futuristic weapons technologies." (Loeb, 2002)

"… the debate over Crusader is about whether to spend roughly $9 billion more to procure some 480 Crusader howitzers or, instead, use funds to accelerate a variety of precision munitions…" (Rumsfeld, 2002:10).

SIMPLE

"Crusader will use a turbine engine that will be common with the M1A2 system enhancement program (SEP) tank." (Emerson, 2002:43)

"… we have… very little expertise in some of the more unproved aspects of the Crusader. For example, the system is designed to be heavily automated, but automated systems fail and the manual back-ups we would need pose [sic] are a challenging dimension that is relatively immature and unproven." (Rumsfeld, 2002:12)

"The design for the Army's Crusader howitzer, for instance, relied on 16 'critical' technologies… but only six of those technologies had ever been demonstrated outside the laboratory when the Crusader entered development in 1994." (Charette, 2008:38)

TINY

"The howitzer's many drawbacks included—being too heavy for rapid deployment." (Tracy, 2004:32)

"If Crusader had been much lighter, it could have been the 'first vehicle of the Objective Force,' said Army Gen. Kevin P. Byrnes, head of the Training and Doctrine Command… The Army stuck with Crusader for many years, despite the weight problems." (Erwin, 2003:1)

"Besides its inability to provide precise targeting, the Crusader is extremely difficult to deploy, Rumsfeld said. Each mobile cannon weighs about 40 tons, and must be accompanied by a resupply vehicle weighing 34 tons." (Veith, 2002:A-20).

"While it is true that Crusader will not fit on a C-130, the aircraft used for strategic airlift are the C-17 and the C-5 transports. Despite the Objective Force requirement to be transportable on a C-130, the strategic aircraft are the ones most likely to be used in an initial strategic deployment." (Emerson, 2002:45)

"Operations will be conducted by a section that is a one-third smaller than today's Paladin section." (Emerson, 2002:44)

OUTCOME

"The howitzer's many drawbacks included—… Being too much of an area fire weapon and lacking precision engagement." (Tracy, 2004:32)

"…to clear the defense budget of what he [Rumsfeld] sees as Cold War relics…" (Loeb, 2002)

"… it is about foregoing a system originally designed for a different strategic context, to make room for more promising technologies." (Rumsfeld, 2002:9).

ANALYSIS

Two months before Crusader was cancelled, advocates claimed the project was on

schedule, on budget and a mere 6 years away from being fielded. However, there was no

evidence the project team valued short timelines, small budgets or simplicity, much less

being small. On the contrary, the project leaders planned to spend a total of 14 years

developing the large, complex system, for a cost of $11B. After more than seven years in

175

development, delivery was still over six years away, which indicates that speed was not exactly a core value for the project leaders.

The fact that Crusader was too large to be transported on a C-130 was dismissed as trivial, since the larger C-5 and C-17 aircraft could provide strategic transportation. This willful defiance of the actual operational requirements (and rejection of the Tiny value) was a major contributor to the program's cancellation.

The outcome was clearly a failure on every level. Project leaders spent $2B over eight years, trying to produce a system that ultimately did not meet the warfighter's needs, present or projected. Crusader's capabilities simply did not match with the required functions in a post-Cold War threat environment, so the additional $9B planned to be spent on the program could not be justified. During the time between program start and 2002, the external threat had changed to such a degree that, even if Crusader had been somewhat smaller, cheaper and more easily deployed, it would have still proven unnecessary. Thus, the project was cancelled to free up billions of dollars for more pressing combat needs, without a single howitzer being delivered.

PROJECT NAME: F-15 Eagle

DATES: 1968 - 1976

STORY SOURCE: Hehs, 1991; Tobias and others, 1982; Burton, 1993; Air Force Fact Sheet; Coates & Neikirk, 1981

RUBRIC SCORE: -20

      F-Score: -5

      I-Score: -5

      S-Score: -5

      T-Score: -5

OUTCOME: A

SAMPLE STATEMENTS:

FAST

Apr 1965: HQAF initiated F-X program, calling for IOC in early 1970's

Sep 1975: First F-15 squadron reached IOC

INEXPENSIVE

"The F-15 was very expensive. It had been twenty-five years since the Air Force had had an air-superiority fighter. It had taken more than five years just to get the program approved. They couldn't afford to take any risks." (Hehs, 1991)

SIMPLE

"The weapons and flight control systems are designed so one person can safely and effectively perform air-to-air combat." (Air Force F-15 Fact Sheet)

"He [Chuck Spinney] pointed out that the high-tech systems designed to make these airplanes more reliable and cheaper to maintain than the older airplanes in the inventory had an exactly opposite effect. The systems failed more often than predicted, and the time and costs to repair the failures were far greater than predicted." (Burton, 1993:74)

TINY

"The F-15 was viewed as highly sophisticated because it is so big and expensive." (Hehs, 1991)

"… the F-15 went through several modification to beef up its wings and add more fuel so it could pull as many g's and fly as far as its little brother [the F-16]. The added weight further increased its maneuvering inferiority to the F-16." (Burton, 1993:21)

OUTCOME

"… a major problem with big, complex fighters is their cost. A large F-15 can usually beat a smaller F-5 in a one-on-one dogfight. But we could buy five F-5's for the price of one F-15. No one claims that an F-15 could beat five F-5's at once. In fact, the Nevada exercises demonstrated that the technical advantages one plane might have over another disappear quickly when more than two planes are involved." (Tobias and others, 1982:367)

"[the F-5] embarrassed the Air Force and Navy in the mock combat tests in 1977, when it fought the vaunted F-15 and F-14 to a virtual draw." (Burton, 1993:99)

"The proud 'air superiority fighters,' F-15s and F-14s costing upward of $30 million apiece, had been fought to all but a draw by a comparatively crude $4 million airplane, the F-5 that Northrop Corp. builds for export to small countries." (Coates & Neikirk, 1981:1)

"One on one, the F-5 was no match for the big planes," he [Col Robert Fay, USAF, ret] said. "The 14s and the 15s could score a kill nearly all the time. But as the numbers went up, such as two F-5s against one F-15 or four F-5's against four F-15s, the picture changed dramatically," said Fay. "Suddenly all the magic weapons were failing." Other analysts… have concluded that the complex radars and other systems in the big planes became confused as the number of combatants increased." (Coates & Neikirk, 1981:12)

"The plane has been plagued with all sorts of engine problems, the most disconcerting of which has been a tendency to stall on takeoff." (Tobias and others, 1982:369)

ANALYSIS

The F-15 is consistently described using words like *big, complex* and *expensive*— and not only by its critics. These labels are often used with pride, as signs of the Eagle's sophistication and importance. These are interesting clues about the values which drove its development. The F-15's project leaders' preference for "high-technology" and their failure to focus on simplicity led to several increases in cost and size, and by some accounts degraded its performance.

The Eagle's price tag reduced the project leaders' risk tolerance, forcing them to pursue greater degrees of certainty and predictability. This drove the cost up even further,

and injected delays into the project as project leaders spent more time and money to ensure a successful outcome.

The F-15's price tag also limited the size of the F-15 fleet, resulting in relatively small numbers of the fighters being fielded. As the ACEVAL/AIMVAL wargame showed, it is not clear the smaller fleet of F-15s would actually be effective against a large fleet of less expensive, less capable fighters (i.e. the F-5). After the disappointing results of these 1977 war games against F-5's, such tests were apparently not repeated.

Despite the mixed outcome in that particular assessment, the F-15 is an outstanding aircraft with a proud operational history. However, it initially struggled with poor reliability, and performed poorly in early exercises against comparable numbers of a simpler, cheaper fighter. As Tobias et al pointed out, "if there is anything less reliable than a complex, sophisticated weapon, it is a *new* complex, sophisticated weapon." (Tobias et al, 1982:369; emphasis in original). These initial shortcomings were eventually resolved over time, at considerable expense.

CO-EVALUATOR ANALYSIS

F=N/A
I=0
S=0
T=0
Outcome=A

PROJECT NAME: V-22 Osprey

DATES: 1981 - 2006

STORY SOURCE: Thompson, 2007; Cordesman & Kaeser, 2008; Johnson, 1992; Day, Stoetzer and Zamora, 2007; Schinasi, 2001; Olson, 2008.

RUBRIC SCORE: -20

>*F-Score: -5*
>
>*I-Score: -5*
>
>*S-Score: -5*
>
>*T-Score: -5*

OUTCOME: A

SAMPLE STATEMENTS:

FAST

"… the V-22 has been 25 years in development, more than twice as long as the Apollo program that put men on the moon." (Thompson, 2007:1)

"Originally, the program was designed to churn out the first of more than1,000 tilt-rotors in less than 10 years for $40 million each." (Thompson, 2007:2)

"The system development phase took 25 years, cost over $18 billion and claimed the lives of 30 people in four crashes of flight tests." (Cordesman & Kaeser, 2008:24)

"In 2001, a Blue Ribbon panel… found the aircraft not maintainable or ready for operational use. It recommended continuing the program at a minimal rate to give it time to sort out the technical problems." (Cordesman & Kaeser, 2008:25)

"Renewed testing and mechanical adjustment further slowed the development and increased the program's cost." (Cordesman & Kaeser, 2008:25)

"Our review of the V-22 program, which is already in low-rate initial production, revealed that the Department planned to proceed with a full-rate production decision without knowing whether new technology could meet Marine Corps requirements; whether the design would work as required; or whether the design could be produced within cost, schedule and quality targets… Specifically, developmental testing was deleted, deferred, or simulated in order to meet cost and schedule goals." (Schinasi, 2001:2)

"Probes into the deadly 2000 crashes revealed that in a rush to deploy the aircraft, the Marines had dangerously cut corners in their testing program. The number of different flight configurations… flown by test pilots to ensure safe landings was reduced by half to meet deadlines. Then only two-thirds of those curtailed flight tests were conducted." (Thompson, 2007:3)

"We weren't trying to rush the schedule. We were event-driven, not schedule-driven. We had the freedom to take our time." (Olson, 2008)

INEXPENSIVE

"… when procurement requirement estimates exceeded 1,000 aircraft, the flyaway cost per aircraft was approximately \$21 million… By 1986, the individual flyaway cost was estimated to be between \$28 million and \$32 million… Some experts suggest that procurement costs could reach \$50-\$55 million per V-22 aircraft by the time the aircraft reaches production." (Johnson, 1992:18-19)

"The Pentagon has put \$20 billion into the Osprey and expects to spend an additional \$35 billion before the program is finished. In exchange, the Marines, Navy and Air Force will get 458 aircraft, averaging \$119 million per copy." (Thompson, 2007:1)

"The aircraft is currently five times more expensive than the system it replaces…" (Cordesman & Kaeser, 2008:24)

"It wasn't about saving a bunch of money – it was about doing it." (Olson, 2008)

SIMPLE

"It is intended to execute a variety of missions for the Marine Corps, the Navy and the Air Force, including troop and equipment transport, amphibious assault, search and rescue, and special operations." (Cordesman & Kaeser, 2008:24)

"… the Navy and Marine Corps reduced some requirements to allow the aircraft to reach operational readiness." (Cordesman & Kaeser, 2008:25)

"We had to do so many fixes so late in the design." (Olson, 2008)

"It was very organizationally complex initially, which led to communication troubles." (Olson, 2008)

TINY

"The Osprey is also three times heavier than the helicopter it replaces." (Cordesman & Kaeser, 2008:24)

"Throughout its development, however, the V-22 enjoyed broad and persistent congressional support. The V-22 program has nearly 2,000 suppliers in over 40 states and created jobs in 276 congressional districts." (Cordesman & Kaeser, 2008:26)

OUTCOME

"After the 2000 grounding, Osprey pilots were told to fly less aggressively, which critics say is the only reason no V-22 has crashed since. 'They keep talking about all the things it can do, but little by little its operations are being more and more restricted,' says Philip Coyle, who monitored the V-22's development as the Pentagon's top weapons tester from 1994 to 2001." (Thompson, 2007:3)

"… the V-22 Osprey arrives in Iraq to make its combat debut—lacking both firepower and the ability to land safely if it loses power at low altitudes." (Cordesman & Kaeser, 2008:24)

"The V-22 continues to suffer problems unusual in an aircraft that first flew in 1989. In March 2006, for example, a just-repaired V-22 with three people aboard unexpectedly took off on its own – apparently the result of a computer glitch." (Thompson, 2007:6)

"Ward Carroll, the top government spokesman for the V-22 program from 2002 to 2005, believes that six Ospreys, about 5% of the fleet, will crash during its first three years of operational flight… 'I'm still not convinced… that the Marine ground pounders are in love with this airplane." (Thompson, 2007:6)

"… rather than taking advantage of the V-22's long-range self-deployment capability, VMM-263 chose to ferry them over on the USS WASP (LHD-1) to avoid dangerous icing conditions. During previous trans-Atlantic flights, the aircraft's de-icing system was shown to be inadequate, resulting in an emergency landing in Iceland due to an engine compressor stall." (Day et al, 2007: 75)

"Results from our analysis put the EH-101 on top in both the net present value and computer simulation models, while the V-22 was superior in measures of overall effectiveness… Even though the Osprey does offer unique capabilities in speed, the benefit over traditional helicopters is marginal." (Day et al, 2007:75)

"We got unbelievable reviews by Marines and Spec Ops users. They love it… I've heard anecdotes from crew chiefs, fliers and other riders – they all just love it. They refuse to call for anything else once they've flown in it." (Olson, 2008)

"On its third Marine deployment, they met all the mission metrics and flew every sortie they were scheduled to fly." (Olson, 2008)

ANALYSIS

The V-22 Osprey development story offers no evidence the project leaders embraced the FIST values. Instead, they predominately deemed it important to develop new, cutting-edge technologies, regardless of the time or cost involved. However, as with other lengthy development projects, it is worth noting that the values expressed by project leaders changed over the years, as new generations of leaders took the helm of this project. Although the changes were sometimes positive, this *values flux* is a type of instability not unlike the types of instability discussed elsewhere in this paper. Towards the end of the development, project leaders seemed to lean towards ensuring cost and

schedule goals were established and met, but this seemed to be for political reasons rather than because being Fast and Inexpensive had any intrinsic operational or technical value.

The Osprey development showed no signs of the Fast value. Not only did the project take 25 years to deliver an operational capability, but in the few instances when project leaders attempted to accelerate the project, they did so by cutting corners on flight tests. A GAO report to Congress pointed out the end result was "knowledge gained in V-22 program falls significantly short of successful programs." (Schinasi, 2001:20). This willingness to cut corners and "maintain schedule" without actually accomplishing the necessary tasks is evidence of *speeding* and is not an indication project leaders were genuinely driven by the Fast value. By eliminating essential safety tests, the project leaders merely created the *impression* of delivering on time. In truth, the system they delivered was grossly inadequate, tragically dangerous, and ultimately required expensive and time-consuming rework.

There is also no evidence project leaders embraced the Inexpensive value. The Osprey program began in 1981 and its costs were already escalating significantly by 1986. In the early 90's, more than a decade after the program began, estimates of the Osprey's per aircraft cost were conservatively estimated at $50 million, more than double the initial estimate. By the time it became operational in 2006, the Osprey actually cost $119 million per copy (Thompson, 2007), which supports the idea that project leaders preferred measures of merit other than Inexpensive. By2005, project leaders seeking to establish a new direction for the Osprey promised to "deliver on time and high quality and at a certain cost," but only after securing the "freedom to take our time" and a

sizeable budget. (Olson, 2008). This approach was an effective and appropriate correction to previous "speeding" behavior, but it falls short of being evidence of the Fast value at work.

As with many new technologies, the Osprey is not a simple machine, and there is no evidence the project leaders valued Simplicity. In fact, the Osprey's complexity and newness is widely viewed as a mark of sophistication among its supporters and advocates. Simpler, mature alternatives are available, such as the EH-101, which is "already flown by military organizations around the world… [and] is already a proven commodity," (Day et al, 2007:76). Project leaders consistently reject these alternatives in favor of the new, exciting "breakthrough" tilt-rotor capability. This preference for the unknown and unproven over reliable, current technology shows the Simple value was not widely accepted on the V-22 project.

Overall, V-22 project leaders showed no interest in the Tiny value. The Osprey is large and heavy when compared with the system it replaces. Tellingly, the workforce was spread across 2,000 suppliers in 40 states. (Cordesman & Kaeser, 2008:26) This means the Osprey was created by a remarkably complex organization, with an organizational footprint that involved 80% of the states. The size of the network of contributors increased the complexity of the endeavor as well, lowing both the Osprey's S-score and the T-score.

Operationally, the Osprey has clearly under-delivered on several fronts, not least of which is its rear-mounted "peashooter" gun. Advocates also like to point out that the V-22 "is capable of self-deployment to virtually any area on earth" (Hildreth, 1994:21),

although the validity of such a claim made in 1994 is difficult to justify, given the fact that the Osprey did not become operational until 2006. The truth is that the self-deployment capability is often not used (Day et al, 2007), despite being one of the Osprey's main selling points.

Hildreth claims that "During Desert Shield/Storm such a capability [the V-22] could have made a critical difference on the battlefield and on a hard-pressed logistics system." (Hildreth, 1994:21). Even granting the conjecture that an operational Osprey would have helped us win bigger, the fact is the Osprey was 15 years too late to be of use during that conflict. No doubt a large fleet of working V-22's would have been extremely helpful at Normandy on D-Day, but it does no good to say a system would have been useful if it had been ready. The fact is, it was not ready in time for Desert Storm, and so was not useful. It had no operational impact on that conflict.

Given the length of time the Osprey spent in development, the persistent scaling-back of operational requirements and the restrictions placed on its use, it is tempting to judge its operational outcome a failure. However, unlike the F-22, the V-22 has actually flown operational missions in combat zones and the feedback to date is very positive (Olson, 2008). Thus, the V-22 is placed in the Success column, but just barely.

It must be noted that the Osprey currently has an extremely short track record of operational use. The fact that it has not yet established much of a record, more than 27 years after the project was begun, is a significantly negative factor. Over the coming years the Osprey may prove itself to be an effective component of American military

strength and more firmly establish itself as a success, or its limitations may come to light

in such a way as to recommend it be placed in the Fail column. Time will tell.

PROJECT NAME: F-22 Raptor

DATES: 1981 - 2005

STORY SOURCES: Muradian and Putrich, 2008; Axe, 2006; GlobalSecurity.org; Hehs, 1998; Charette, 2008; Walker, 2006; Thompson, 2009; Young, 2008.

RUBRIC SCORE: -20

> *F-Score: -5*
>
> *I-Score: -5*
>
> *S-Score: -5*
>
> *T-Score: -5*

OUTCOME: F

SAMPLE STATEMENTS:

FAST

November 1981: Air Force identifies need for advanced tactical fighter to replace the F-15

September 1985: The formal ATF request for proposal is issued.

15 Dec 2005: The F-22 achieved Initial Operating Capability. (Global Security).

F-22 Acquisition cycle time (months): 231 (Walker, 2006:59)

"As it had done with the proposal for the previous phase, the Air Force delayed the submittal date for the dem/val [demonstration/validation] proposals. This time the delay was put off for prototyping." (Hehs, 1998)

"The rollout of the prototypes was initially scheduled for mid 1989, but ongoing slippages delayed this." (Global Security)

"… the F-22 EMD program schedule was rephased in early 1993 and again in mid 1994. The F-22 program was rescheduled due to funding shortages. The rescheduling resulted in an 11-month delay in the first flight (to 59 months from E&MD start, twice as long as average recent experience) and an 18 month delay in the planned Milestone III date. These delays should not be construed as further reducing risks…" (Global Security)

"The F-22A design is essentially complete, but it matured slowly, taking over 3 years beyond the critical design review to meet best practice standards." (Walker, 2006:60)

"The Air Force established the F-22A modernization and improvement program in 2003" [two years *before* IOC] (Dodaro, 2008:59)

INEXPENSIVE

F-22 estimated procurement cost: $32.14B (FY06$) for 181 aircraft

Program Unit Cost: $361.3M per aircraft (Walker, 2006:59)

"… in late 1985, the USAF sent out a letter to the competing companies to encourage teaming… The program was going to be expensive and big." (Hehs, 1998)

"Technical issues are not the biggest challenge for the F-22 program, affordability is. Air Force cost estimates indicated the program could exceed the Congressional cap of $37.6 billion for production of 333 aircraft…" (Global Security).

"Since 1997 the costs of avionics has increased by over $951 million or 24 percent and problems discovered late in the program were the major contributor." (Walker, 2006:60)

"The Air Force is counting on $2.2 billion in future cost reduction plans to offset estimated cost growth and enable the program to meet the latest production cost estimate." (Walker, 2006:60)

"… no coherent effort has been made to contain costs, or to procure a cheaper and less sophisticated version of the aircraft." (Cordesman & Kaeser, 2008:15)

SIMPLE

"In addition to being America's most prominent air-superiority fighter, the F-22 evolved from its original concept to become a lethal, survivable and flexible multi-mission fighter. By taking advantage of emerging technologies the F-22 has emerged as a superior platform for many diverse missions including intelligence gathering, surveillance, reconnaissance and electronic attack." Lockheed Martin Website (http://www.lockheedmartin.com/products/f22/ accessed 10 Sep 08)

"The F-22 incorporated revolutionary advances in airframe, low-observable technology, maneuverability, engines, materials, and integrated avionics systems." (Global Security).

"The three critical F-22A technologies (supercruise, stealth, and integrated avionics) appear to be mature. However, two of these technologies, the integrated avionics and stealth, did not mature until several years after the start of development." (Walker, 2006:60)

"There were several design changes required to the aircraft as a result of operational testing." (Walker, 2006:60)

"Integrating stealth, speed, and maneuverability became the fundamental challenge of the ATF program. No one had ever attempted such a complex combination before." (Hehs, 1998)

TINY

"Maneuverability requirements tend to increase the size of the wings and tails and make the engines bigger than necessary for supercruise alone, all of which makes stealth more difficult to achieve." (Hehs, 1998)

OUTCOME

"Defense Secretary Robert Gates… [pointed] out that 'the F-22 has not performed a single mission' in either Iraq or Afghanistan." (Charette, 2008:37)

"Officials believed deploying the Raptor so near Iran would cause a 'strategic dislocation' in the region, sources said." (Muradian and Putrich, 2008)

"…to top Pentagon leaders, sending the plane into the Iraq fight was overkill. Loren Thompson of the Lexington Institute agreed, saying the F-22 is ill-suited to counterinsurgency operations in Iraq. 'Most of what the F-22 brings isn't useful to fighting insurgents,' Thompson said." (Muradian and Putrich, 2008)

"… the Marine Corps aviators of All-Weather Fighter Attack Squadron 332, deployed to Al Asad in western Iraq, had told me their old $40-million F/A-18D Hornet equipped with sensor pods are better suited to counter-insurgency combat than the $130-million F-22A Raptors, which don't even have hard points for pods." (Axe, 2006)

"… the Air Force has not demonstrated the F-22A can achieve its reliability goal of 3 hours mean time between maintenance. It does not expect to achieve this goal until the end of 2009 when most of the aircraft will have already been bought." (Walker, 2006:60)

"The fighter's purpose is described largely in technical terms rather than tied to a comprehensive strategy for the Air Force…" (Cordesman & Kaeser, 2008:13)

"[Secretary of Defense Gates] bluntly stated in February that the F-22 has no role in the war on terror." (Hoffman, 2008:1)

"The F-22s that exist are ready to fly only 62% of the time and haven't met most of their performance goals." (Thompson, 2009:25)

"The recent mission capable data for FY2008 on F-22s had a mission capable rate somewhere in the 62 percent range. I think that's troubling. Follow-on operation tests in 2007 raised operational suitability issues and noted that the airplane still does not meet most of its KPPs. It meets some, but not all. Key performance parameters. The trend in those operational tests, there was an IOT&E, a follow-on test I think in 2004 and a follow-on test in 2007. The trend is actually negative. The maintenance man hours per flying hour have increased through those tests. The last one was a substantial increase. The airplane is proving very expensive to operate, not seeing the mission capable rates we expected." (Young, 2008)

ANALYSIS

Like the Comanche development team, F-22 project leaders clearly were committed to developing innovative new technology rather than delivering a simple, effective system on schedule. Despite persistent performance shortfalls, the team's primary value seemed to be incorporation of complex, high-tech solutions. The project

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leaders apparently did not deem it important to deliver a low-cost, simple solution on a short timeline, and were willing to sacrifice cost, schedule and usability in order to integrate newer, unproven technologies.

In terms of operational outcome, a strong case can be made that the Raptor is a failure so far. The F-22A was originally envisioned to counter "two hypothetical Soviet aircraft," (Charette, 2008:36). However, the Soviet Union collapsed in 1991, fourteen years before the F-22A declared IOC, so its effectiveness against that particular threat was zero. It can be argued that the US must still deal with the weapons produced by the former USSR (and current Russian Federation) as they are propagated throughout the world, but its effectiveness against those threats is currently unproven. In fact, the very presence of those threats is also questionable. Similarly, the assertion that currently available aircraft (or hypothetically upgraded versions the Air Force could have developed but didn't) are unable to meet those threats has also not been proven.

Along with its failure to demonstrate it meets reliability goals, the F-22A has been deemed ineffective in fighting insurgents, the primary threat currently facing US forces. It has also been judged politically unsuitable for deployment near Iran, for fear of unnecessarily provoking that country. Although IOC was declared in 2005, the F-22 has not flown a single mission over Afghanistan or Iraq as of March 2009. These are significant operational shortfalls, and are the true measure of a program's success.

Physically, the F-22A apparently outperforms all current fighter aircraft in the world today, but this project assesses Operational success, not technical success. Weapon systems are supposed to bring capabilities to the field, not simply supersede existing

systems already in the inventory. In fact, considering the fact that F-15's routinely fly actual combat missions and F-22's do not, one might ask in what sense the F-22 is the superior aircraft. Since the Raptor has yet to fly any operational missions four years after going IOC, despite US involvement in two concurrent wars, the only possible "operational impact" grade it can receive is an F for failure.

Further, as the Air Force Studies Board explained, "Programs that failed, in the committees view, may have delivered successful products but were well outside the reasonable expectations of the original program and were only successful in delivering products after the addition of substantial unplanned funding and a substantial extension of the original schedule." (AF Studies Board, 2008:26) This clearly describes the situation for the F-22.

Unlike the Comanche helicopter or A-12 Avenger, the F-22 team actually delivered operational aircraft and achieved IOC. This opens the possibility of it eventually being used in combat, should the right kind of war come along, and so it could become something other than an operational failure. Despite its current low availability rate (62%), there is every indication it would perform admirably at such a time as its capabilities were needed. If so, the F-22's grade could be changed from an F to an A. However, whether or when its capabilities will be needed or effective in future combat situations remains to be seen. The fact that it has not yet established a positive operational track record in the years since it went IOC requires me to give it an F.

PROJECT NAME: Comanche Helicopter

DATES: 1983 - 2004

STORY SOURCE: Wayne, 2003; Merle, 2004; Congressional Budget Office, 1997; Bender, 2004; Global Security, 2008.

RUBRIC SCORE: -20

> *F-Score: -5*
>
> *I-Score: -5*
>
> *S-Score: -5*
>
> *T-Score: -5*

OUTCOME: F. Cancelled in 2004, delivered 0 aircraft

SAMPLE STATEMENTS:

FAST

"It had a long and troubled history…" (Merle, 2004:A1)

"The helicopter is still in the development stage, which will continue at least through 2004. As recently as 1992, the Army had planned to start buying Comanches in 1996, but it has since delayed the start of production until 2005." (CBO, 1997)

"Skeptics of the program suggested that unmanned planes capable of performing the Comanche's surveillance and precision-strike role will be available to the Army prior to the maturing of the Comanche system." (Global Security, 2008)

"The first helicopter will be combat-ready in September 2009, three years behind the previous schedule. Production and purchase of the first helicopters would begin in fiscal 2006, one year later than planned under the previous schedule." (Global Security, 2008)

INEXPENSIVE

"The utility version was dropped in 1988, however, because the program had become too costly." (CBO, 1997)

"The Army would have spent $14 billion on the commence program through 2011 without getting aircraft significantly more capable than the upgraded Apaches it already plans to buy, Army officials said." (Merle, 2004: A2)

"These changes in the objective and size of the program have caused the cost of each Comanche helicopter – expressed in 1997 dollars – to more than double since the program began, from $11 million in 1985 to $26 million based on the Army's 1996 estimate. Furthermore, the Comanche has become more expensive to acquire than the Army's current generation of attack helicopter." (CBO, 1997).

"The new Acquisition Decision Memorandum (ADM) formally approving the plan added about $3.4 billion to the Comanche's $3.1 billion development program." (Global Security, 2008).

"Matt Broder, a spokesman for Sikorsky, in response to a request for comment, said, "Our company's policy is not to respond to rumors. As far as we are concerned, the program is fully funded and on schedule." Boeing officials said the Chicago-based company had not been informed of any program cancellation. "The Comanche program is on track and schedule. We have not been notified about any change in the program status," said Boeing spokesman John Morrocco." (Dunham & Emery, 2004)

SIMPLE

"Government watchdog groups lauded the [cancellation] decision, saying the program has long been plagued with cost overruns, schedule delays, and an overzealous desire to include unproven technologies." (Bender, 2004)

"Some analysts argue that the threats the Comanche is likely to face would not demand the very sophisticated stealth, avionics, and aeronautic technologies slated for the new helicopter." (CBO, 1997).

"According to the DOT&E, technical challenges remained for software integration and testing of mission equipment, weight reduction, radar signatures, antenna performance, gun system performance, and aided target detection algorithm performance." (Global Security, 2008).

TINY

"Empty weight projections for Block I, II and III aircraft were slightly higher than weight goals for each block." (Global Security, 2008)

OUTCOME

"The Army yesterday cancelled development of the $39 billion Comanche helicopter after 21 years of escalating costs, technical glitches and redesigns during a program that failed to produce a single operational aircraft." (Merle, 2004:A1)

"… the Comanche, which was conceived at the height of the Cold War, will no longer need to counter threats of the same scale or sophistication as those it was designed to thwart." (CBO, 1997).

"Some analysts argue that the threats the Comanche is likely to face would not demand the very sophisticated stealth, avionics, and aeronautic technologies slated for the new helicopter." (CBO, 1997).

"Based on analysis by DOT&E of current designs and limited testing on a contractor range, the radar warning receiver and two communications antennas did not meet some RCS allocations. The satellite receiver antenna did not meet performance requirements, and the radar warning sensitivity was marginal. Efforts to reduce the RCS would have been likely to adversely affect the performance of already marginal antennas." (Global Security, 2008).

ANALYSIS

The Comanche project was clearly committed to developing innovative new technology. Despite persistent performance shortfalls, the project leaders' primary value seemed to be incorporation of complex, high-tech solutions. There is no evidence project leaders deemed it important to deliver a low-cost, simple solution on a short timeline. Rather, the evidence suggests they were more than willing to sacrifice cost, schedule and usability in order to ensure the Comanche's technologies were cutting-edge, however unproven or unreliable.

While some optimistic commentators initially referred to it as "the centerpiece of America's 21st century war-fighting strategy" (Moore, 1998) the Comanche was clearly a failure on every level. Although officials from Boeing and Sikorsky insisted the program was "on track and on schedule" up until the day it was cancelled, the actual cost and schedule far exceeded estimates. More importantly, the aircraft did not perform as required. Ultimately, the external threat changed to such a degree that, even if it had worked, it would have proven operationally unnecessary. The project was cancelled after spending nearly $7B over two decades. The cancellation enabled the Pentagon to avoid spending the additional $14B budgeted to continue developing and purchasing the aircraft.

PROJECT NAME: Future Imagery Architecture (FIA)

DATES: 1996 - Sept 2005

STORY SOURCE: Taubman, 2007; Anselmo & Butler, 2005; Pae, 2001

RUBRIC SCORE: -20

> *F-Score: -5*
>
> *I-Score: -5*
>
> *S-Score: -5*
>
> *T-Score: -5*

OUTCOME: F – Project Cancelled Sept 2005

SAMPLE STATEMENTS:

FAST

"The panel reported that the project, called Future Imagery Architecture, was far behind schedule and would most likely cost $2 billion to $3 billion more than planned." (Taubman, 2007: 1)

"… the contract would discourage overruns or delays with financial penalties." (Taubman, 2007:7)

"The National Reconnaissance Office announced its decision on Sept. 3, 1999, after studying the bids for nearly a year." (Taubman, 2007:8)

"As costs escalated, Boeing cut back on testing… If a component failed, Boeing, lacking a backup approach, had to return to square one, forcing new delays." (Taubman, 2007:9)

"The electro-optical satellites… are close to five years behind schedule." (Anselmo & Butler, 2005:1)

INEXPENSIVE

"… the program was threatening to outstrip its $5 billion budget." (Taubman, 2007:1)

"… they advised Mr. Teats to seek an infusion of $700 million." (Taubman, 2007:1)

 "By the time the project, known by its initials F.I.A., was killed in September 2005 – a year after the first satellite was originally to have been delivered – cost estimates ran as high as $18 billion." (Taubman, 2007:2)

"… Team 377 [Boeing's secret planning group] requested $100 million just to draft the proposal…" (Taubman, 2007:6)

"F.I.A. was grossly underfunded." [said Mr. Young, chairman of one of the panels that examined the project] (Taubman, 2007:7)

"… the satellite, under pressure from Congress to control costs, would no longer have a reserve fund." (Taubman, 2007:7)

"I took what it had cost to build a comparably complex system before, figured in inflation, and realized the project would cost $4 billion more than the government had planned and Boeing was proposing." (Taubman, 2007:7)

"The cost of an overrun was so ruinous that the strongest incentive it provided to the contractor was to prove they were on cost." (Taubman, 2007:10)

"… the government had approved an additional $3.6 billion. Still, rather than recommending cancellation, the Young panel said the program could be salvaged with even more financing and changes in the program and schedule." (Taubman, 2007:10)

"… the system's price tag has grown from $6 billion to at least $15 billion." (Anselmo & Butler, 2005:1)

SIMPLE

"But perhaps more striking is that the multiple failures that led to the program's demise reveal weaknesses in the government's ability to manage complex contracts…" (Taubman, 2007:1)

"… an internal assessment that questioned whether its lofty technological goals were attainable given the tight budget and schedule." (Taubman, 2007:2)

"… the satellite agency, hobbled by… the loss of seasoned staff members, lacked the expertise to make sound engineering evaluations of its own…" (Taubman, 2007:2)

"The satellites were loaded with intelligence collection requirements, as numerous intelligence and military services competed to influence the design. Boeing's initial design for the optical system that was the heart of one of the two new satellite systems was so elaborate that optical engineers working on the project said it could not be built." (Taubman, 2007:2)

"A torrent of defective parts… repeatedly stalled work." (Taubman, 2007:2)

"The leaders of Team 377 realized that the best hope of impressing the satellite agency was to design a system that was cheaper and better—more technologically daring—than anything Lockheed might propose." (Taubman, 2007:6)

"The goal… was a revolutionary zoom lens… As for the radar-imaging satellite, Boeing designed a relatively simple system with one major exception:… it would produce a far stronger radar signal than any previous satellite had. Pulling off such complex new technology typically requires extensive testing and work on multiple solutions to especially difficult problems." (Taubman, 2007:6-7)

"… outside engineers questioned the photo satellite's intricate optical system… it soon became clear the system could not be built." (Taubman, 2007:8-9)

"… the government's addition of more stringent requirements, the new satellites are looking more like the 'Battlestar Galacticas' they were supposed to replace than the simple spacecraft envisioned in 1999." (Anselmo & Butler, 2005:1)

TINY

"The endeavor will require 5,000 engineers, technicians and computer programmers over the next five years, and that will just be for the initial design and development." (Pae, 2001:1)

OUTCOME

"It took two more years, several more review panels, and billions more dollars before the government finally killed the project – perhaps the most spectacular and expensive failure in the 50-year history of American spy satellite projects." (Taubman, 2007:1)

ANALYSIS

Anselmo & Butler claim that "FIA… was procured under the faster-better-cheaper mindset of the 1990's," (Anselmo & Butler, 2005:2), and early reports describe the project in terms of using smaller, cheaper satellites. For example, Taubman writes:

> "In 1996, a commission created by the director of central intelligence recommended building a fleet of light, small, relatively inexpensive satellites… The panel also envisioned saving money and time by taking advantage of technologies and parts developed by commercial satellite companies… Congress demanded rigid spending guidelines for the satellite project…" (Taubman, 2007:4)

Despite this initial vision, it is not clear the project leaders really accepted or understood these values. In fact, despite congressional pressure and contractual clauses designed to minimize cost and schedule, neither the government personnel nor the contractors seemed to have a favorable opinion of the FIST value set.

Looking back, many of the involved parties blame FIA's failure on the strict cost and schedule constraints, as if to say they could have succeeded if they had only been allowed to overrun the budget and schedule. This is the antithesis of the FIST values. Despite the frequent claims that allowing overruns would have solved FIA's problems, the project did quickly overrun both cost and schedule, to no avail, making that assertion seem spurious. But whether it is a valid complaint or not, the project leaders' willingness

to attribute FIA's failure to inadequate funding and insufficient time is clear evidence that the team rejected the Fast and Inexpensive values. Project leaders who embrace the FIST values think it is good and important to have a short schedule and a small budget and view these constraints as elements of success. Project leaders who value FIST never say "We would have succeeded if we'd had a lot more time and money."

It is worth pointing out that FIA's attempt at faster-better-cheaper (FBC) technology came in the late 1990's, when NASA was experiencing similar problems with their own FBC initiatives. Both organizations' problems can be traced to two primary sources: complexity and formalization. In their late 1990's missions, NASA and the NRO seem to have under-appreciated the role of simplicity in FBC projects, as applied to the technology under development and the organizations themselves. Both NASA and the NRO attempted to build highly complex systems with short schedules and small budgets, and attempted to turn the FBC approach into a mechanical, process-oriented, contractually-driven checklist rather than a humanistic, talent-oriented, value-driven effort. This is the opposite of the Simple value, and is not consistent with the successful implementations of the FBC initiative.

Writing about NASA's failures with FBC missions in 1999, McCurdy explains "proponents of the approach created failure when they reduced cost and schedule faster than they lessened complexity." (McCurdy, 2001:25) The NRO appears to have made a similar error with FIA. Project leaders expected to reduce cost and schedule without reducing complexity. They then blamed their failures on inadequate resources and began to overrun. Had they really understood and implemented the FIST values, they would

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have looked for opportunities to simplify, streamline and shrink the system, seeking to improve outcomes by reducing complexity rather than seeking additional money and time.

Further, the FBC and FIST approaches tends to have a higher failure-per-attempt rate than traditional approaches, so they often requires multiple attempts. These multiple attempts are possible because of the time and money savings associated with a FIST project. FIA expected a complex organizational structure to deliver a complex system with a low cost and short schedule, and get it right the first time. The idea of experiencing a failure and having to start over was unacceptable. This is not consistent with the FIST values.

Along with ignoring the Simple value and rejecting the Inexpensive value, Boeing seriously misunderstood the Fast value. This led them to fall into a classic speeding trap, in which they cut back on early testing in the interest of faster delivery. When the system failed tests later in development, the delays were extensive and expensive, far exceeding the cost or time associated with doing the early tests in the first place. This short-sighted perspective on the value of speed has been lampooned since Aesop's story of the tortoise and the hare, and Boeing should clearly have known better.

Another significant aspect of the problems was excessive optimism on the part of Boeing officials. The term "excessive optimism" is actually a euphemism for dishonesty, and the failure to be honest about the project's status contributed significantly to the eventual outcome. Taubman writes:

> "Boeing's point man on the job was Ed Nowinsky… he acknowledged that Boeing frequently provided the government with positive reports on the troubled

project… Mr. Nowinski said, 'but it was certainly in my best interest to be very optimistic about what we could do.'" (Taubman, 2007:2)

This is further evidence that the FBC approach was mere window dressing, and not evidence of the project leader's actual values. Boeing and NRO leaders were determined to maintain the *appearance* of being on time and on budget, all the while increasing complexity and seeking opportunities to add additional funding and time to the FIA project.

In the end, FIA was cancelled, earning a description as "the most spectacular and expensive failure in the 50-year history of American spy satellite projects." (Taubman, 2007:1)

PROJECT NAME: Division Air Defense System (DIVAD) aka Sergeant York

DATES: 1977 - 1985

STORY SOURCE: Ditton, 1988;

RUBRIC SCORE: -20

> *F-Score: -5*
>
> *I-Score: -5*
>
> *S-Score: -5*
>
> *T-Score: -5*

OUTCOME: F

SAMPLE STATEMENTS:

FAST

"Instead of the normal ten to fifteen years needed to bring a defense weapon system through research and development to the production phase, seven years was allotted for the DIVAD program." (Ditton, 1988:3).

"There was, however, no flexibility in the June 1980 date when the first prototypes were to be delivered to Fort Bliss, Texas." (Ditton, 1988:3)

"Both contractors, after more than two years of work, unveiled their prototypes on schedule… But problems were already evident. 'Prototypes from both contractors were unexpectedly immature,' according to a 1986 General Accounting Office report." (Adam, 1987:30)

"… the fixed-price options… put pressure on decision makers to proceed with production on schedule, despite technical difficulties." (Ditton, 1988:7)

"… greater priority has been given to adhering to the schedule than to correcting some serious system performance problems at this time." (Ditton, 1988:8)

"The ambitious goal was to… achieve operational capability by October 1983—less than six and a half years from the start. This was fast compared with most other Army programs. It took about eight years to develop the M-1 tank, for example." (Adam, 1987:30)

"Colonel Russell W. Parker, project manager of Army air defense gun systems, stated… 'We expect this somewhat unorthodox approach to permit a much reduced development time, thus resulting in an earliest fielding date, albeit with higher but accepted risks.' The additional risks stemmed from reducing the required testing and combining the gun's follow-on development with initial production." (Adam, 1987:30)

"…calendar schedule compliance had a higher priority than test matrix completion… the combination of these factors precluded complete execution of the test plan." (Adam, 1987:33)

INEXPENSIVE

"… a fixed-price incentive type contract… incorporated twelve firm requirements and forty-three other requirements, which the contractor could trade off for cost and schedule benefits." (Ditton, 1988:4)

"The Army successfully controlled costs until contract termination." (Ditton, 1988:7)

"Such high-tech guns, costing more than $6 million apiece, or more than twice the cost of an M-1 tank…" (Adam, 1987:29)

"[BGen] Cannon [chairman of the DIVAD source selection board] reminded the General Dynamics team that the paramount evaluation factors were system performance and cost." (Adam, 1987:30)

SIMPLE

"… the Army adopted a 'hands off' policy. The two contractors competing for the production contract were free to develop a DIVAD in any manner they chose, provided that the specifications were met." (Ditton, 1988:4)

"… companies were given maximum flexibility and were guaranteed minimum meddling by the Government." (Adam, 1987:30)

"… an amalgam of existing components put together under an accelerated program…" (Adam, 1987:28)

"Another twist to the acquisition strategy was the use of off-the-shelf components to build the gun." (Adam, 1987:30)

"… the DIVAD gun system was supposed to be an integration of proven major components, including the M-48A5 tank chassis, twin Swedish Bofors 40 millimeter guns, and radars from the F-16 fighter." (Ditton, 1988:4)

"… the specifications were unworkable because they attempted the technologically impossible. Although each major subsystem was a proven component, the sum of the components could not match contract requirements, much less battlefield reality. The F-16 radar operates on detection of movement and was successful at acquiring moving targets. Unfortunately, it had difficulty acquiring stationary targets. The computer fire direction system could not adequately track moving targets because it could not anticipate where a moving aircraft would go next." (Ditton, 1988:6)

"… most of the software for the York had to be newly developed… 'Errors were consistently observed at all levels of software testing.'" (Adam, 1987:32)

TINY

"Its goal was to develop a bigger and better gun than the Gepard [a German air defense gun]" (Adam, 1987:29)

"Greater ranges would require larger projectiles, which cannot be fired as quickly as smaller ones. For example the 20-mm Vulcan fires 3000 rounds a minute; the 40-mm York fired only 60." (Adam, 1987:29)

OUTCOME

"… on August 27, 1985, the Secretary of Defense canceled the DIVAD procurement… Sixty-five DIVADs had already been built, and 1.8 billion dollars had been spent on the program." (Ditton, 1988:6)

"The DIVAD procurement is an excellent example of many of the problems with modern weapon acquisition programs." (Ditton, 1988:6)

"… for the guns to shoot down nine of the 11 targets, many of the aircraft had to make multiple passes." (Adam, 1987:33)

ANALYSIS

The Army's DIVAD program has all the appearances of a FIST project, with frequent assertions in support of several of the FIST values and many instances of contractual, procedural and technical decisions being made based on a desire to cut cost and schedule. The contractor was given the flexibility to trade-off requirements for cost and schedule savings, which seems to indicate that Fast and Inexpensive mattered more than high-technology or performance. However, upon closer examination, this project is revealed to be a pseudo-FIST effort, with a significant emphasis on *appearing* to be fast and inexpensive, rather than actually embracing or understanding how to apply these values.

At first glance, the fact that the DIVAD team was given an aggressive timeline seems to indicate the presence of the Fast value. However, the project leaders' determination to avoid a schedule slip led them to ignore "serious system performance problems." While the team achieved a high degree of "calendar schedule compliance," one might ask what it means to be on schedule if the system does not actually do what it

needs to do. A project that fails to meet the critical performance requirements by the necessary date cannot be considered "on schedule." That is, the *program* might have been on schedule, simply because June followed May, but the *system* clearly was not. And while the Fast value allows project leaders to trim unnecessary activities, the DIVAD project skipped the part where they were supposed to build something that works, and ended up merely speeding.

Similarly, the literature asserts that project leaders "successfully controlled costs" on the DIVAD development. This is not an accurate statement. Project leaders merely controlled *spending*, not cost, which is a horse of a different color. That is, they spent as much as they'd planned to spend in the time allotted, but they purchased far less than their customers needed. By purchasing less, they were not genuinely expressing the Inexpensive value. They were expressing something entirely different, an *ugly twin* that appears similar from a distance but is fundamentally dissimilar.

The Earned Value Management (EVM) approach demonstrates the difference between controlling spending and controlling cost [See diagrams labeled Figure 1 and Figure 4 below]. Had the DIVAD team used such an approach, the truth of their values and performance would have come to light much sooner. Rather than merely comparing spending over time to the budget over time, the DIVAD team should have looked at the amount of work accomplished and the capabilities established (the "value") over that time period. Their failure to do so indicates, once again, that rather than value Inexpensive *solutions*, they simply valued Inexpensive *programs*. They therefore settled for the illusion of Inexpensive, with disastrous results.
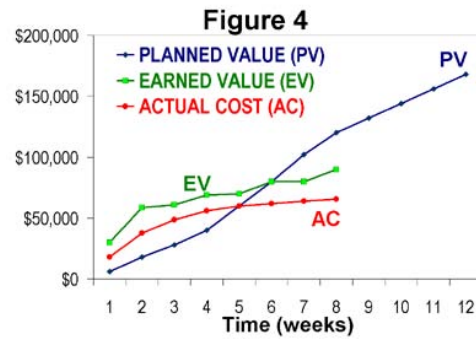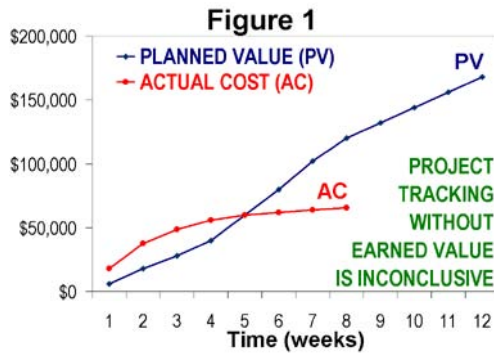
(Figures are from Wikipedia entry on Earned Value Management, accessed 31 Oct 08: http://en.wikipedia.org/wiki/Earned_value_management)

Much is made of the Army's decision to simplify the procurement process, freeing Ford from the complexities of government regulation and requirements. However, the Army's "hands off" policy was unfortunately accompanied by an "eyes shut and ears plugged" approach, creating the appearance of simplifying the situation in the short term, while actually making things more complicated down the road. There is a difference between not interfering with the contractor's decisions and not really being aware of them, a distinction the DIVAD project leaders did not seem to grasp. Simply handing a contract to a company and asking them to report back when the job is complete is not simple – it is simplistic, which is quite different from the Simple value.

The decision to incorporate mature, proven technology has the *appearance* of simplicity, but not the substance. This approach is only effective if the technology selected for integration into the system actually does what it needs to do. Thus, using the F-16 radar creates the appearance of using "mature, proven technology," except for the fact that the F-16 radar is only good at detecting moving targets, while the DIVAD needed to acquire stationary ones. Similarly, building the DIVAD onto an existing tank chassis would only make sense if that chassis was powerful enough to haul the DIVAD's

full weight. In fact, "the M-48's 750-horsepower engine was designed to power a 50-ton tank, not the 60-ton Sergeant York vehicle." (Adam, 1987:32) Since the DIVAD's weight exceeded the engine's designed capacity by 20%, one might argue that the M-48, while mature, for this purpose was neither proven nor appropriate. Subsequent testing showed that it was simply not up to the task.

Interestingly, while much of the DIVAD's hardware was reuse, the software was primarily a new development. Not surprisingly, it was plagued with errors. Recall, this development took place in the early 1980's, when computer programming was a much less mature discipline than it is today. So, the DIVAD team's decision to use mature (albeit inadequate) hardware is overwhelmed by the use of immature, buggy software.

The Tiny value is the least ambiguous of the four. Not much is said about the size of the team, but the vehicle was 20% larger than the tank from which it got it chassis and the large 40mm munitions were sufficiently large to significantly reduce the rate of fire, limiting the gun's effectiveness.

The emphasis on appearances extends to the operational testing. The literature indicates the system managed to shoot down 9 out of 11 helicopters, which sounds like an apparently impressive 82% kill rate. However, since "many of the aircraft had to make multiple passes," (Adam, 1987:34), the kill rate was actually much lower. We can conservatively assume, for the sake of argument, that fewer than half the targets made one extra pass each, for a total of 5 additional passes. The DIVAD then would have a kill rate of 9 out of 16, for a much less impressive 56% kill rate. The actual rate is unknown, but probably less than 56%.

In order to be effective and influential, guiding values must be deeply held. The FIST values, properly understood and implemented, go to the core of each project leader and team member. Settling for the mere appearance of the FIST values, cutting corners and creating the illusions of speed and thrift – these are the antithesis of the FIST value set. The DIVAD project shows no evidence of the depth typical in projects with a high FIST score, despite its surface-level similarities.

The program was cancelled, and DIVAD is often pointed to as an "excellent example of many of the problems with modern weapon acquisition programs." (Ditton, 1988:6). DIVAD's failure was so complete and widely publicized that US Senator Jim Sasser (D-TN) asked that the project be known solely as DIVAD rather than Sergeant York, out of respect of his state's prominent World War I hero.

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22. FIST Comic #1, *Defense AT&L* Mar/Apr 06
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27. The Pursuit of Courage, Judgment and Luck: A Rogue Risk Rant, *Defense AT&L* Mar/Apr 07
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14. ABSTRACT

In order to understand why organizations make certain decisions and target certain outcomes, it is useful to understand their priorities and preferences, commonly referred to as "values." This research explores the relationship between the technical values held by system development teams and the operational effectiveness of the systems those teams produce. Specifically, it examines the impact of a value set called FIST (Fast, Inexpensive, Simple, Tiny) on DoD and NASA system development projects, and investigates the correlation between the FIST values and operational outcomes. The findings show that the FIST value set enhances project stability, increases the project leader's control and accountability, optimizes failure, fosters "luck," and facilitates learning. These benefits of the FIST approach all support the goal of ensuring the organization delivers systems which are "available when needed and effective when used." FIST is therefore recommended as an effective approach to system development, and several heuristics are provided to facilitate understanding and application of these values.

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